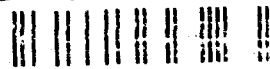


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DEVELOPMENT OF NEW SHIPBOARD LAUNDRY FORMULATION



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NAVY CLOTHING AND TEXTILE RESEARCH FACILITY
NATICK, MASSACHUSETTS

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INTRODUCTION

The Navy Clothing and Textile Research Facility (NCTRF) was tasked by Navy Resale and Services Support Office (NAVRESSO) to evaluate a two-step laundry product manufactured by Pennwalt Corporation and to determine its effectiveness with respect to current Navy shipboard laundering practices.

The present laundering formulas used aboard ship require the use of several chemical products which are individually dispensed during the laundering cycle to achieve good performance. The potential increase of this process by reducing the presently required five laundering chemicals. The use of a two-step laundering procedure such as the Pennwalt Corporation N-DET-2 product may also result in reduction of storage space requirements and special handling procedures, because of the corrosive nature of some of the products.

However, basic questions required resolution prior to implementation of this concept. These included whether sufficient cleansing of soiled Navy clothing items could still be obtained if the laundering chemicals were changed as well as the effect of the new products on appearance, color change, and special finishes present on the Navy uniforms.

Close collaboration between NCTRF, NAVRESSO, and Pennwalt Corporation led to the performance of a shipboard test aboard the USS RANGER in San Diego, CA and laboratory testing at NCTRF. The objective was to evaluate under both laboratory and shipboard conditions the cleansing ability of the present shipboard laundering chemicals versus those of the two-step laundering product manufactured by Pennwalt Corporation.

This report discusses the findings of the study and details the methods used to obtain these findings.

TEST EQUIPMENT

(1) Laboratory - Fresh water laundry operations in the laboratory were performed using a programmable Pellerin/Milnor washer/extractor, 35 pound capacity. Dryings were performed using an American Laundry Machine, tumble dryer, 50 pounds capacity. Simulation of sea water laundering was performed in an Atlas launder-o-meter, and dried in a Precision mechanical convection oven.

(2) Shipboard - Three different washers were used. They consisted of a programmable 60 and 200 pound Milnor washer-extractor and a 100 pound Dyna-washer-extractor. Two American Laundry Machine tumble dryers were also used. They had a capacity of approximately 50 and 100 pounds.

TEST MATERIALS:

The following L-1 garments and experimental materials were selected for this evaluation because of their washability, fiber content, special finishes, color and degree of utilization in Navy clothing.

The items listed under Section A were exposed to the chemicals listed in Section B.

A. - Garments/Materials

- (1) 65/35% Polyester/Cotton fabric, 8.0 oz/yd², White Experimental
- (2) 75/25% Polyester/Wool fabric, 6.0 oz/yd², Blue 3346 Experimental
- (3) 95/5% Nomex/Kevlar fabric, 4.5 oz/yd², Blue 3375
- (4) Men's Jumper, 100% Polyester CNT, 6.8 oz/yd², White 3006
- (5) Men's Shirt, 100% Polyester CNT, 6.8 oz/yd², Khaki 3729
- (6) Women's Skirt, 100% Polyester texturized warp/spun filling, 6.0 oz/yd², Blue 3346
- (7) Men's Shirt, 65/35% Polyester/Rayon, 6.0 oz/yd², Blue 3346
- (8) 100% FRT Cotton, Chambray, 5.5 oz/yd², Blue 3372
- (9) 100% FRT Cotton, Denim, 12.0 oz/yd², Blue 3371
- (10) Neckerchief, 100% Acetate, 3.3 oz/yd², Blue 3218
- (11) Service White Hat, 100% Cotton, 7.0 oz/yd², White 3013
- (12) Men's Shirt, 65/35% Polyester/Cotton, 4.5 oz/yd², White 3013
- (13) Men's Trouser, 50/50% Polyester/Cotton, 7.0 oz/yd², White 3017
- (14) Men's Chambray Shirt, 65/35% Polyester/Cotton, 3.5 oz/yd², Blue 3372
- (15) Men's Denim Trouser, 50/50% Polyester/Cotton filling, 35/65% Polyester/Cotton warp, 10.0 oz/yd², Blue 3371
- (16) 100% Cotton, white towels
- (17) Nylon/Cotton socks, white and blue
- (18) Nylon/Cotton/Wool cushion sole socks, blue
- (19) 100% Cotton, white briefs
- (20) 100% Cotton, white boxer shorts
- (21) 50/50% Cotton/Nylon, Woodland Camouflage, 6.8 oz/yd²

B. - Detergents/Chemicals

- (1) Formula I at 160°F
 - (a) Detergent - P.D.-245-C
 - (b) Alkali
 - (c) Non-ionic
 - (d) Dry organic bleach (chlorine bleach)
 - (e) Clorox 2
 - (f) Sour blue
- (2) Penwalt's Formula at 160°F
 - (a) N-DET-2
 - (b) Sour/bacteriostat

PREPARATION OF TEST MATERIALS:

In order to determine the performance of the Pennwalt two-step product and the present formulation, side by side laundering tests were performed with known stains. A standard soil stain composed of motor oil, vegetable oil, mineral oil and vacuum dust was applied to an area of the garment or material with a brush and dried overnight. White materials were soiled with a stain composed of Arco Graphite motor oil in accordance with the NCTRF soil release test method.

In addition to these stains, a set of standard swatches obtained from the International Fabricare Institute (IFI) were included in the evaluation. The swatches allow the measurement of soil removal effectiveness, the effect of bleach on color change, and influence of laundering chemicals on whiteness, tensile strength, resin finishes and brighteners. The swatches utilized were as follows:

- (1) Soil stains on 100% cotton
- (2) Blood stains on 100% cotton
- (3) Bleach effect for dyed 100% polyester
- (4) Whiteness and yellowness for 100% cotton
- (5) Tensile strength of polyester/cotton
- (6) Bleached 65/35% polyester/cotton with resin and optical brightener finishes

All laundering tests performed aboard ship and in the laboratory consisted of ten laundering cycles for each laundering condition. The exceptions of ten laundering cycles for each laundering condition. The exceptions to the above were Pennwalt's laundering formula with simulated sea water which consisted of five cycles and Formula I with double the required amount of chlorine bleach for 15 cycles.

SHIPBOARD TESTS IN SAN DIEGO:

Test Conditions

- (1) Formula I with chlorine bleach at 160°F
- (2) Formula I without chlorine bleach at 160°F
- (3) Formula II at 160°F
- (4) Pennwalt's laundering formulation at 160°F

LABORATORY TESTS:

Test Conditions

- (1) Formula I with chlorine bleach at 160°F
- (2) Formula I without chlorine bleach at 160°F
- (3) Formula I with double chlorine bleach at 160°F
- (4) Formula I with Clorox 2 at 160°F
- (5) Formula II at 140°F
- (6) Pennwalt's laundering formula at 120°F, 140°F, and 160°F

- (7) Pennwalt's laundering formula with simulated sea water conditions at 140°F
- (8) Germicidal testing at 120°F, 140°F, and 160°F

TEST PROCEDURES:

All white, blue and khaki items were exposed to the same conditions as on the ship with the exception that Formula II was used at a temperature of 140°F and not 160°F. In addition, all of the white, blue and khaki items were exposed to temperatures of 120°F and 140°F using Pennwalt's products. Simulated sea water launderings at a temperature of 140°F were also performed on the white materials.

Sampling of Materials - Garment/material samples were drawn during both the shipboard and laboratory tests after 1, 5, and 10 laundering cycles to determine progressive effects of the laundering chemicals on cleanability as well as on physical and visual properties. This was accomplished by staining the white garments and experimental fabrics with artificial soil and Acro Graphite motor oil. Spectrophotometric reflectance measurements of all the items prior to soiling, after soiling, and after laundering were recorded to determine the percent soil removed and color change after washing.

The standard Navy Wash formula I was used at 160°F with only the whites, because it calls for the use of chlorine bleach. Pennwalt's formula, which contains an oxygen (non-chlorine) bleach, was used for all whites, blues and khakis at 120°F, 140°F, and 160°F, as well as under simulated sea water conditions. Pennwalt's laundering procedure is basically the same as Formula I except that the Formula I detergent, alkali, nonionic and chlorine bleach are replaced by one product which contains all of the above chemicals except that an oxygen bleach is used instead of a chlorine bleach. The blue sour in Formula I is replaced by Pennwalt's sour/bacteriostat which Pennwalt claims provides protection against bacteria buildup. Formula I was also used without the chlorine bleach for the blues, khakis and whites at a temperature of 160°F. These tests provided data on the effectiveness of the present laundering formulations versus the Pennwalt's formula using a full array of Navy garments. The starching step was eliminated for all materials, except for the 100% cotton denim trousers (aboard USS RANGER), because it is not required in the laundering of 100% synthetic or synthetic/cotton blend textile items.

The germicidal evaluation was performed by the Science and Technology Laboratory, NRDEC and also by the United States Testing Company, Inc.. Tested articles included socks, underwear, and towels. The tested articles were inoculated with a bacteria and then washed using Formula I with chlorine bleach and Pennwalt's laundering formula at 120°F, 140°F, and 160°F. The final rinse water and the inoculated articles were examined for presence of bacteria.

The IFI test soil cloths were laundered along with the test materials and garments. During the laundering operation, wash water temperature, pH and water hardness were monitored, as well as the temperature of the dryer air. After each laundering, the garments and the IFI test cloths were dried in a tumble dryer between 160°F and 180°F.

All laundered items were subsequently evaluated in the NCTRF laboratory for shrinkage, tensile strength, and appearance. The white fabrics were also rated for soil release, and the flame retardant fabrics were tested for vertical flammability resistance after laundering. The laundered IFI test swatches were evaluated by IFI laboratory for determination of tensile strength, soil removal, and effect of bleach on yellowness, whiteness, optical brighteners and resin finishes.

DISCUSSION OF RESULTS:

Germicidal Evaluation -

Studies performed by both NRDEC and U.S. Testing indicated that there was no significant difference with respect to bacterial kill between the Pennwalt Detergent/sour/bacteriostat and Navy Formula I (Table 1). Both formulations, regardless of running temperature (120°F, 140°F, 160°F) provided similar reductions in vegetative bacterial numbers (>11 log), while spore numbers were virtually unaffected.

A skin irritation test performed by U.S. Testing in accordance with the Federal Hazardous Substances Act showed no signs of irritation to erythema and eschar after 72 hours, using Pennwalt's products.

It should be noted that the bacteriostat used in conjunction with the sour for Pennwalt's formulation is a commercially available product (not manufactured by Pennwalt) that has been approved by the Environmental Protection Agency (EPA). Reports on the germicidal evaluation by U.S. Testing and NRDEC are attached as Appendices D and E.

Soil Removal -

A summary of the mean for the percent of soil removed for all of the blue, khaki, and white materials laundered in the laboratory and also those aboard ship are presented in Figures 1, 2, 3, 4, and 5. Percent of soil removed was based on the Y tristimulus value reflectance readings of the fabric before soiling, after soiling and after laundering as follows:

$$\% \text{ Soil Removal: } \frac{A-B}{C-B} \times 100$$

A = Laundered Sample
B = Soiled Sample
C = Original Sample

All blue (Figures 2 and 5) and Khaki (Figure 4) items, regardless of where they were laundered (shipboard or laboratory), were exposed to Formula I without the presence of chlorine bleach and also Pennwalt's Formula at 120°F, 140°F and 160°F. Test results indicate that there was no statistically significant difference between the two detergents for these items.

Table 1 - Log Reduction[†] of Bacterial Counts
in Navy Laundry at Different Temperatures

Microorganisms	120°F (49°C)			140°F (60°C)			160°F (71°F)		
	1	2	3	1	2	3	1	2	3
<u>E. Coli</u> <u>(ATCC 11229)</u>	4.9	>11.0	>11.0	>11.0	>11.0	>11.0	>11.0	>11.0	>11.0
<u>S. Aureus</u> <u>(ATCC 6538)</u>	5.0	>11.0	>11.0	>11.0	>11.0	>11.0	>11.0	>11.0	*
<u>B. Globigii</u>	N/A	0.64	0.85	N/A	1.03	1.26	N/A	1.35	1.36

[†] Log reduction in this experiment is defined as the reduction in total number of bacterial added initially. This reduction is calculated from the number of bacteria recovered from all the cycles of washing based on experimental results.

For comparison of efficacy of kill of microorganisms, a 6.0 log reduction over baseline was considered adequate disinfection.

* No Data

1 = No Detergent

2 = Formula I

3 = Pennwalt

ATCC = American Type Culture Collection

Test results on white fabrics are shown in Figures I and 4 for the laboratory and shipboard trials, respectively. For the most part, Pennwalt's product at 160°F exhibited a higher mean value for soil removal for all laundering cycles than the standard Navy formula (76% versus 69%). Also noted was an equivalent degree of soil removal with Pennwalt's product at a temperature of 120°F and 140°F as compared to Navy Formula I. The differences in results between the three temperatures at which the Pennwalt product was used were found to be insignificant. Therefore, this concept would have to be further investigated to confirm the laboratory results.

Yellowness/Whiteness Index -

The degree of yellowness/whiteness for all white materials was determined in accordance with ASTM Test Method E-313. Yellowness and Whiteness Index was calculated on the basis of Y and Z tristimulus values.

Formula used was as follows:

$$\text{Yellowness Index (YI)} = 100 (1-B/G)$$

$$B = 0.84, (Z)$$

$$G = Y$$

Definition: Increase # of laundering cycles, increase yellowness.

$$\text{Whiteness Index (WI)} = 4B-3G$$

Definition: Increase # of laundering cycles, decrease whiteness.

Yellowness Index -

Figure 6 and Table 1A indicate that the first cycle for Formula I without chlorine bleach shows less yellowness than the standard material in the shipboard tests. This is due to the bleeding of a denim garment which was accidentally laundered with the white items. This resulted in some blue dye onto the materials, negating any detection of yellowness. However, upon continuous laundering, the blue dye from the denims was removed and an increase in yellowness was exhibited with subsequent launderings. The Yellowness Index for all laboratory and shipboard laundry testing indicated that Formula I (with chlorine bleach) increased the yellowness of the fabrics to a greater degree than Pennwalt's formula. Also, no significant difference in Yellowness Index was observed when running the Pennwalt formulation under various laundering temperatures (120°F, 140°F, and 160°F).

Figure 7 and Table 2 show a higher Yellowness Index for Formula I than for Formula I run with double the required amount of chlorine bleach. This is due to a soil stain that was applied to the samples in Formula I

and not to Formula I with double the bleach. The soil created a laundering environment whereby some of the soil redeposited itself onto the fabrics, thus increasing the Yellowness Index. Doubling the chlorine bleach, as indicated by Figure 2 and also based on previous studies performed by the Navy will definitely increase the yellowness of the white fabrics, destroy some functional finishes, and deteriorate the physical properties.

Table IA - Yellowness Index Values Obtained from
Shipboard Laundering Samples

Sample Material	Laund. Cycle	Formula I	Formula I - N.B.	Pennwalt's
		YI	YI	YI
100% Polyester	0	-	-	-
CNT, White	1	0.4	-2.2	0.5
Jumper	5	0.2	1.1	-0.1
	10	0.2	0.3	0.3
50/50 Polyester/ Cotton, White	0	-	-	-
	1	-0.3	-1.8	-1.0
Trouser	5	0.7	0.8	-1.8
65/35 Polyester/ Cotton, White	0	-	-	-
	1	1.2	0.1	1.4
Fabric, USNA	5	2.9	2.7	1.5
	10	3.1	2.7	2.0
65/35 Polyester/ Cotton, White	0	-	-	-
	1	0.7	-	0.3
Shirt	5	-	-	-
	10	-	-	-
100% Cotton, White	0	-	-	-
Hat	1	2.1	-2.4	1.2
	5	2.6	0.6	0.0
	10	2.7	1.0	-1.2

YI - Yellowness Difference
N.B. - No Bleach

Table 2 - Yellowness Index Values Obtained from Laboratory Laundered Samples

Sample Material	Cycle	Formula I DB	Formula I NR	Formula I Clorox	Pennwalt @ 120°F	Pennwalt @ 140°F	Pennwalt @ 160°F	Pennwalt - Sea Water @ 140°F
		YI	YI	YI	YI	YI	YI	YI
100% Polyester COT, White Jumper	0	-	-	-	-	-	-	-
	1	4.1	1.8	2.6	2.1	3.7	2.7	5.6
	5	3.1	3.8	2.6	1.5	0.0	2.8	6.2
	10	2.7	2.0	3.3	1.2	3.0	1.9	-
	15	-	2.1	-	-	-	-	-
50/50 Poly- ester/Cotton Jumper	0	-	-	-	-	-	-	-
	1	3.2	2.0	1.5	0.0	0.6	0.9	4.0
	5	4.3	4.4	3.8	-0.2	1.8	0.2	3.3
	10	8.6	5.2	4.4	0.7	2.5	0.6	-
	15	-	7.4	-	-	-	-	-
65/35 Poly- ester/Cotton, White Fabric USNA	0	-	-	-	-	-	-	-
	1	3.0	2.7	2.3	-0.2	1.6	2.1	4.9
	5	5.6	3.8	3.9	-0.2	3.6	2.4	3.7
	10	7.4	5.8	4.8	0.5	3.4	2.8	-
	15	-	7.9	-	-	-	-	-
65/35 Poly- ester/Cotton Shirt	0	-	-	-	-	-	-	-
	1	1.8	1.4	0.5	-0.9	-	-	2.0
	5	3.0	2.0	2.3	-1.0	0.0	-	1.3
	10	4.6	2.4	2.4	-0.5	1.4	-	-
	15	-	4.1	-	-	-	-	-
100% Cotton White Hat	0	-	-	-	-	-	-	-
	1	4.5	3.2	3.0	3.1	1.2	2.4	5.4
	5	5.6	4.1	5.4	3.4	5.0	2.0	4.5
	10	7.8	6.7	4.7	4.3	1.8	1.8	-
	15	-	8.1	-	-	-	-	-

DB = Double the Required Bleach

NR = No Bleach

YI = Yellowness Differences

Whiteness Index -

Figures 8, 9, and Tables 3, 4 depict the Whiteness Index for all laboratory and shipboard launderings. In general, the trend was a decrease in the whiteness index as the number of cycles increase. Similar to the yellowness index measurements, deterioration of whiteness was found to be less with the Pennwalt Formula than with Formula I with chlorine bleach. Improvement in both the whiteness and yellowness index as were found for Formula I launderings performed with double the chlorine bleach.

Color Difference -

As shown in Figures 10 and 11, laundering the blue and khaki materials listed on page 2 (Garments/Materials) with the Pennwalt formula produced similar color difference results to the Navy Formula I without chlorine bleach. Also, when run at different temperatures, Pennwalt's formulation produced the same color differences for all fabrics in all cases.

The CIE lab color difference values for the laboratory and shipboard launderings were found to be $L^* \pm 250$, $a^* \pm 0.65$, $b^* \pm 0.65$ and $L^* \pm 2.45$, average of all the samples for each laundering cycle. The results indicate that the laundry detergent has no adverse effect on the color of the garment/materials. A color difference of 2.50 CIE lab units in the lightness direction is an acceptable change after ten laundering cycles.

The CIE lab color difference range in Figures 10 and 11 would have been significantly reduced had the 100% acetate neckerchief material which lost much of its color during laundering been eliminated from the evaluation. This material, under realistic conditions, is either washed by hand at a lower temperature or is dry cleaned.

Figures 12 and 13 demonstrate the effect of Formula I with no bleach versus that of the Pennwalt formula on the color change of utility uniforms. As can be seen, the color differences range is very wide due to the fading or bleeding of the denim material. Again, no significant differences were noted between laundering formulas or the laundering sites.

Infrared Reflectance -

Infrared reflectance measurements were performed on the Army/Marine Corps Woodland camouflage printed cloth in an effort to ascertain whether the reflectance properties are destroyed through laundering. Three fabric samples were laundered with the Pennwalt formulation for 10 cycles. Reflectance measurements on the four colors were obtained initially and after 10 laundering cycles and found to still be in accordance with MIL-C-44031B requirements.

Soil Release (Whites) -

Soil release studies were conducted in an effort to: a. determine whether a soil release finish had been applied to any of the white materials; b. to assess the durability of the finish; c. to indicate the effectiveness of the detergents on removal of the Arco Graphite motor oil stain. The test results depicted in Table 5 indicate that no significant differences were recorded between laboratory and shipboard launderings with either the Pennwalt or Navy formula. However, a slight decrease in soil release was observed with the Pennwalt product at a temperature of 120°F and 140°F, and also samples laundered under simulated sea water conditions. Soil release studies confirmed that multiple laundering cycles have a positive impact on the removal of the oil stains.

Table 3 - Whiteness Index Values Obtained from
Shipboard Laundered Samples

Sample Material	Laund. Cycle	Formula I	Formula I - N.B.	Pennwalt's
		WI	WI	WI
100% Polyester	0	-	-	-
CNT, White	1	4.8	3.0	4.7
Jumper	5	3.2	11.8	3.3
	10	4.8	10.0	8.4
50/50 Polyester/ Cotton, White	0	-	-	-
Trouser	1	0.6	3.7	-2.4
	5	6.5	10.0	-4.4
	10	11.8	13.2	0.5
65/35 Polyester/ Cotton, White	0	-	-	-
Fabric, USNA	1	4.9	6.7	5.3
	5	11.4	13.3	4.7
	10	13.7	14.4	8.9
65/35 Polyester/ Cotton, White	0	-	-	-
Shirt	1	3.3	-	1.8
	5	-	-	-
	10	-	-	-
100% Cotton, White	0	-	-	-
Hat	1	9.2	5.9	5.4
	5	11.5	10.0	1.2
	10	13.0	11.2	-1.3

WI - Whiteness Difference
N.B. - No Bleach

Table 4 - Whiteness Index Values Obtained from Laboratory Laundered Samples

Sample Material	Cycle	Formula I	Formula I D3	Formula I NR	Formula I Clorox 2	Pennwalt @ 120° F	Pennwalt @ 140° F	Pennwalt @ 160° F	Pennwalt - Sea Water @ 140° F
		WI	WI	WI	WI	WI	WI	WI	WI
100% Polyester Cvt, White Jumper	0	-	-	-	-	-	-	-	-
	1	21.0	7.8	18.5	15.5	19.4	15.0	28.5	28.5
	5	15.6	14.7	17.0	14.3	1.4	15.0	29.7	29.7
	10	13.7	9.1	18.4	16.5	15.4	11.2	-	-
	15	-	9.7	-	-	-	-	-	-
50/50 Poly- ester/Cotton White Trouser	0	-	-	-	-	-	-	-	-
	1	13.7	8.4	-10.5	7.6	3.5	4.6	20.0	20.0
	5	13.8	17.4	-1.4	15.9	7.7	1.7	18.4	18.4
	10	29.9	21.1	-1.1	17.4	9.7	4.8	-	-
	15	-	28.9	-	-	-	-	-	-
65/35 Poly- ester Cotton, White Fabric USNA	0	-	-	-	-	-	-	-	-
	1	10.9	9.3	8.2	8.7	5.6	6.8	20.9	20.9
	5	19.1	12.8	11.4	13.8	12.5	7.9	16.8	16.8
	10	25.1	19.8	15.0	16.8	11.5	8.7	-	-
	15	-	27.6	-	-	-	-	-	-
65/35 Poly- ester/Cotton Shirt	0	-	-	-	-	-	-	-	-
	1	6.7	7.1	-	1.9	-	-	13.5	13.5
	5	11.0	8.8	-	8.3	0.7	-	10.3	10.3
	10	16.3	10.7	-	8.9	4.1	-	-	-
	15	-	17.1	-	-	-	-	-	-
100% Cotton White Hat	0	-	-	-	-	-	-	-	-
	1	19.1	11.9	10.1	9.5	5.9	10.6	24.6	24.6
	5	22.4	15.0	8.3	17.7	19.7	8.7	22.1	22.1
	10	29.6	25.8	9.9	14.6	7.5	7.5	-	-
	15	-	30.4	-	-	-	-	-	-

D3 = Double the Required Bleach

NR = No Bleach

WI = Whiteness Difference

Table 5 - Soil Release Ratings* of Laboratory and Shipboard Laundering Samples

Sample Material	Formulas	1 Cycle		5 Cycles		10 Cycles	
		Lab	Ship	Lab	Ship	Lab	Ship
100% Polyester CNT, White Jumper 1/	Formula I	2.5	2.7	3.2	3.1	3.0	3.3
	Formula I No Bleach	2.9	2.7	3.7	3.2	3.7	3.2
	Formula I Clorox 2	2.8	-	3.3	-	3.3	-
	Pennwalt's @ 120°F	2.7	-	2.9	-	3.2	-
	Pennwalt's @ 140°F	3.0	-	3.9	-	2.9	-
	Pennwalt's @ 160°F	2.6	2.9	3.0	3.2	3.0	3.1
	Sea Water @ 140°F	2.3	-	3.0	-	-	-
50/50 Polyester/ Cotton, White Trouser	Formula I	2.6	2.9	3.0	3.0	3.4	3.2
	Formula I No Bleach	3.0	3.0	3.0	3.0	3.0	3.2
	Formula I Clorox 2	2.9	-	3.3	-	3.3	-
	Pennwalt's @ 120°F	2.9	-	2.9	-	3.0	-
	Pennwalt's @ 140°F	3.3	-	3.0	-	3.3	-
	Pennwalt's @ 160°F	2.5	2.9	3.1	3.1	3.5	3.2
	Sea Water @ 140°F	3.0	-	3.0	-	-	-
65/35 Polyester/ Cotton, White Fabric, USNA	Formula I	3.5	3.3	3.5	3.4	3.4	3.7
	Formula I No Bleach	3.5	3.2	3.5	3.6	3.7	3.6
	Formula I Clorox 2	3.5	-	3.7	-	3.6	-
	Pennwalt's @ 120°F	3.0	-	3.1	-	3.2	-
	Pennwalt's @ 140°F	3.3	-	3.3	-	3.4	-
	Pennwalt's @ 160°F	3.4	3.2	3.5	3.6	3.4	3.9
	Sea Water @ 140°F	3.0	-	3.2	-	-	-
65/35 Polyester/ Cotton, White Shirt	Formula I	2.6	4.2	3.0	-	3.0	-
	Formula I No Bleach	-	2.9	-	-	-	-
	Formula I Clorox 2	3.4	-	3.4	-	3.3	-
	Pennwalt's @ 120°F	3.1	-	3.3	-	3.4	-
	Pennwalt's @ 140°F	-	-	3.4	-	3.3	-
	Pennwalt's @ 160°F	-	2.9	-	-	-	-
	Sea Water @ 140°F	2.8	-	2.5	-	-	-
100% Cotton White Hat	Formula I	3.0	3.4	3.0	3.4	3.5	3.5
	Formula I No Bleach	3.5	3.5	4.0	3.7	3.5	3.6
	Formula I Clorox 2	3.4	-	3.3	-	3.4	-
	Pennwalt's @ 120°F	3.0	-	3.3	-	3.3	-
	Pennwalt's @ 140°F	3.3	-	3.2	-	3.3	-
	Pennwalt's @ 160°F	3.5	3.5	3.5	3.4	3.5	3.7
	Sea Water @ 140°F	3.0	-	3.0	-	-	-

* Based on NCTRF Soil Release Rating Chart

1/ Fabric did not possess a soil release finish. A 100% polyester CNT white fabric with a soil release finish was subjected to 10 cycles of Formula I and a soil release rating of 5.0 was obtained.

The 100% polyester CNT white jumper had the lowest soil release rating and highest degree of soil-redeposition of any of the materials tested regardless of the formula employed. This test determined that the jumpers did not possess a soil-release finish (a rating of 2.5 and evidence of soil-redeposition are indications of an untreated fabric). This was verified by laundering a sample of the present standard CNT material possessing a soil release finish in the laboratory. This sample had a rating of 5.0 with excellent anti-soil redeposition properties. It should be noted that the 65/35 polyester/cotton soil release treated Naval Academy fabric was found to provide adequate soil release properties (an average rating of approximately 3.5).

Flammability

Test Method No. 5903 of Federal Standard 191A was performed on all of the flame retardant fabrics (100% FRT cotton denim and chambray and 95/5% Nomex/Kevlar), both initially and after multiple laundering cycles. Test results, which are provided in Table 6, show no significant differences in flammability between fabrics laundered with the Pennwalt formula and those laundered with the Navy Formula I without chlorine bleach. Neither formula had an adverse effect on any of the flame retardant materials. There was a slight improvement, however, in flame retardancy for the Nomex/Kevlar material when laundered in the laboratory with the Pennwalt formula at a temperature of 160°F. The after-glow decreased from an initial value of 13.6 seconds in the warp direction to 7.2 seconds after ten laundering cycles, while the char length was virtually unchanged.

It should also be noted that initially, both flame retardant treated (FRT) cotton denim and chambray materials did not meet the military specification requirement of 2.0 seconds after glow when subjected to Navy Formula I without bleach. There were no further flammability failures observed on the FRT chambray material after the first laundering cycle, but results for the FRT denim continued to be erratic throughout the 10 cycles. Both fabrics, for the most part, did meet all specification requirements after laundering with the Pennwalt formula, both initially and after multiple launderings at temperatures of 120°F, 140°F, and 160°F.

Tensile Strength

As noted in Tables 7 and 8, there were no significant differences recorded in the tensile strength between the materials laundered by the Navy formula or the Pennwalt formula, regardless of temperature, amount of bleach or whether they were laundered in the laboratory or aboard ship.

Tear Strength

As indicated in Table 9, there was a decrease in tear strength for all of the white fabrics after 15 launderings using Formula I with double the required amount of chlorine bleach. Based on these results and those presented earlier, it must be concluded that using more than the required amount of chlorine bleach does far more harm than good.

Table 6 - Flammability Results After Laundering - Federal Test Method #5903

Material Launder Cycle Fab Direct.	Initial		Formula I NF						Pennwalt @ 120°F						Pennwalt @ 140°F						Pennwalt @ 160°F						
	W	F	1/	W	F	1	W	F	1	W	F	5	W	F	1	W	F	5	W	F	1	W	F	5	W	F	10
<u>Laboratory</u>																											
100% FRT																											
Cotton Denim																											
Fabric																											
AF (Sec)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AG (Sec)	2.6	2.5	2.8	3.2	3.3	3.7	10.6	6.4	2.1	2.0	2.0	1.9	1.9	2.1	2.5	2.3	2.3	2.4	2.2	2.0	1.6	1.6	1.3	2.2	2.6	1.9	1.9
CL (in)	2.3	2.1	2.7	1.9	2.1	1.8	1.6	1.4	2.8	2.5	2.1	2.4	2.3	2.6	2.4	3.1	2.6	2.2	2.4	2.4	2.1	1.4	1.8	2.1	1.9	1.9	
100% FRT																											
Cotton Chambray																											
Fabric																											
AF (Sec)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
AG (Sec)	2.9	2.8	1.2	1.1	1.5	2.0	2.2	2.4	1.7	1.9	1.8	2.0	1.9	2.0	2.0	2.1	2.1	1.8	1.9	2.0	1.0	1.0	1.1	1.3	1.2	1.1	
CL (in)	2.5	2.8	3.0	2.7	2.6	2.7	2.8	2.8	3.7	3.3	3.5	3.5	3.6	3.8	3.8	3.6	3.7	3.5	3.6	3.3	2.9	2.8	3.0	2.9	3.3	3.4	
95/5 Nomex/ Kevlar Blue																											
Fabric																											
AF (Sec)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
AG (Sec)	13.6	8.5	18.5	11.9	14.0	13.8	10.9	8.5	10.4	7.9	8.6	10.8	10.1	9.4	9.5	8.6	9.7	8.2	12.8	19.6	6.2	5.1	7.2	6.7	7.2	6.8	
CL (in)	1.4	1.3	1.3	1.3	2.2	2.1	1.4	1.3	2.6	1.6	2.4	2.5	2.8	2.0	2.7	2.2	2.6	2.4	2.6	3.5	1.4	1.4	1.6	1.5	1.6	1.5	

Table 6 - Flammability Results After Laundering - Federal Test Method #5903 (Cont'd)

Material Laund Cycle Fab Direct.	Initial		Formula 1 IIRB										Pennwalt @ 120°F										Pennwalt @ 140°F										Pennwalt @ 160°F													
	W	F	1/	W	F	1	W	F	5	W	F	10	W	F	1	W	F	5	W	F	10	W	F	1	W	F	5	W	F	10	W	F	5	W	F	10	W	F	10	W	F					
Shipboard																																														
100% FRT Cotton Denim Fabric																																														
AF (Sec)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
AG (Sec)	2.6	2.5	2.4	2.0	2.2	1.7	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0		
CL (in)	2.3	2.1	2.1	1.6	1.5	0.8	1.6	1.7	1.7	1.7	1.7	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6		
100% FRT Cotton Chambray Fabric																																														
AF (Sec)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
AG (Sec)	2.9	2.8	1.2	1.0	1.1	1.3	1.6	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	
CL (in)	2.5	2.8	3.2	3.0	2.9	2.8	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	
95/5 Norex/Kevlar Blue Fabric																																														
AF (Sec)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
AG (Sec)	13.6	8.5	7.5	7.4	8.4	6.9	8.0	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2
CL (in)	1.4	1.3	1.2	1.9	1.0	1.1	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3

IIRB = No Bleach
AF - After Flame
AG - After Glow
CL - Char Length

Table 7 - Tensile Strength (lbs.) of Materials Subjected to Laboratory Launderings

Material	Laund. Cycle	Formula I		Formula I NR		Formula I DB		Formula I Clorox 2		Pennwalt @ 120°F		Pennwalt @ 140°F		Pennwalt @ 160°F	
		Warp	Fill	Warp	Fill	Warp	Fill	Warp	Fill	Warp	Fill	Warp	Fill	Warp	Fill
35/65 Polyester/ Cotton Denim Trousers	0	N/A	N/A	260	85	N/A	N/A	N/A	N/A	260	85	260	85	260	85
	1			206	112					238	137	241	123	220	108
	5			202	111					216	135	231	134	201	117
	10			196	118					234	136	220	83	161	100
	15			-	-					-	-	-	-	-	-
100% Polyester Cotton White Jumper	0	256	210	256	210	256	210	210	210	256	210	256	210	256	210
	1	243	200	247	199	-	-	196	196	245	205	237	204	253	207
	5	247	194	242	198	248	210	218	218	235	205	223	188	252	190
	10	246	198	233	197	-	-	198	198	242	206	247	211	231	197
	15	-	-	-	-	245	208	-	-	-	-	-	-	-	-
50/50 Polyester/ Cotton White Trousers	0	202	110	202	110	202	110	110	110	202	110	202	110	202	110
	1	193	104	189	106	-	-	92	92	194	103	198	110	176	105
	5	191	97	171	83	195	116	107	107	190	108	191	113	201	103
	10	182	104	165	88	-	-	109	109	190	108	192	114	165	83
	15	-	-	-	-	181	111	-	-	-	-	-	-	-	-
65/35 Polyester/ Cotton Chambray Shirt	0	N/A	N/A	84	60	N/A	N/A	N/A	N/A	84	60	84	60	84	60
	1			81	57			89	89	88	58	88	58	79	55
	5			77	56			90	90	82	61	82	58	81	52
	10			83	58			87	87	88	64	88	55	77	58
	15			-	-			-	-	-	-	-	-	-	-
100% Polyester Cotton Khaki Shirt	0	N/A	N/A	255	243	N/A	N/A	N/A	N/A	255	243	255	243	255	243
	1			290	236					277	214	257	235	301	258
	5			275	253			288	288	297	235	297	230	264	238
	10			292	244			262	262	293	227	293	221	297	245
	15			-	-			-	-	-	-	-	-	-	-

Table 7 - Tensile Strength (lbs.) of Materials Subjected to Laboratory Launderings (Cont'd)

Material	Laund. Cycle	Formula I		Formula I NA		Formula I D3		Formula I Clorox 2		Pennwalt @ 120°F		Pennwalt @ 140°F		Pennwalt @ 160°F	
		Warp	Fill	Warp	Fill	Warp	Fill	Warp	Fill	Warp	Fill	Warp	Fill	Warp	Fill
65/35 Polyester/ Cotton White Shirt	0	152	68	-	-	152	68	68	152	152	68	152	68	-	-
	1	159	80	-	-	-	-	84	179	-	89	-	-	-	-
	5	138	79	-	-	160	67	89	177	167	89	167	83	-	-
	10	142	78	-	-	-	-	84	159	167	78	161	80	-	-
	15	-	-	-	-	158	68	-	-	-	-	-	-	-	-
100% FRT Cotton Chambray Fabric	0	N/A	N/A	111	65	N/A	N/A	N/A	111	111	65	111	65	111	65
	1	-	-	103	58	-	-	-	113	115	62	115	65	104	58
	5	-	-	96	61	-	-	103	103	109	63	109	64	96	59
	10	-	-	96	63	-	-	95	95	90	54	90	65	87	59
	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-
100% FRT Cotton Denim Fabric	0	N/A	N/A	196	142	N/A	N/A	N/A	196	196	142	196	142	196	142
	1	-	-	176	131	-	-	190	190	193	128	193	136	176	133
	5	-	-	182	135	-	-	173	173	193	123	193	129	178	129
	10	-	-	163	136	-	-	183	183	198	127	198	141	165	127
	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95/5 Nomex/ Kevlar Blue Fabric	0	N/A	N/A	241	150	N/A	N/A	N/A	241	241	150	241	150	241	150
	1	-	-	230	151	-	-	240	240	239	150	239	157	219	151
	5	-	-	212	139	-	-	237	237	231	157	231	154	223	145
	10	-	-	224	151	-	-	244	244	239	155	239	158	221	152
	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 7 - Tensile Strength (lbs.) of Materials Subjected to Laboratory Launderings (Cont'd)

Material	Laundering Cycle	Formula I		Formula I NB		Formula I DB		Formula I Clorox 2		Pennwalt @ 120°F		Pennwalt @ 140°F		Pennwalt @ 160°F	
		Warp	Fill	Warp	Fill	Warp	Fill	Warp	Fill	Warp	Fill	Warp	Fill	Warp	Fill
65/35 Polyester/ Cotton White Fabric USA	0	326	104	326	104	326	104	326	104	326	104	326	104	326	104
	1	286	91	300	91	-	-	96	96	317	100	298	105	289	92
	5	277	92	294	94	98	98	94	95	304	95	294	101	280	90
	10	283	91	302	92	-	-	92	95	292	95	301	103	291	91
	15	-	-	-	-	285	91	-	-	-	-	-	-	-	-
75/25 Polyester/ Wool Blue Fabric	0	N/A	N/A	152	132	N/A	N/A	N/A	152	152	132	152	132	152	132
	1	-	-	145	131	-	-	-	151	149	134	149	136	142	128
	5	-	-	139	120	-	-	-	149	147	135	147	132	134	117
	10	-	-	144	127	-	-	-	148	145	131	145	129	137	126
	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-
100% Polyester/ TW/SF Woman's Skirt	0	N/A	N/A	353	132	N/A	N/A	N/A	353	353	132	353	132	353	132
	1	-	-	257	120	-	-	-	274	269	116	269	128	260	113
	5	-	-	271	125	-	-	-	267	269	133	269	126	263	115
	10	-	-	250	114	-	-	-	262	269	122	269	127	248	119
	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-
65/35 Polyester/ Rayon Blue Shirt	0	N/A	N/A	146	135	N/A	N/A	N/A	146	146	135	146	135	146	135
	1	-	-	140	134	-	-	-	148	147	146	147	126	136	140
	5	-	-	142	132	-	-	-	152	145	134	145	134	138	115
	10	-	-	145	133	-	-	-	145	143	138	143	124	174	147
	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TW/SF = Texturized Warp/Spun Filling

DB = Double the Required Bleach

NB = No Bleach

Table 8 - Tensile Strength (lbs.) of Materials
Subjected to Shipboard Launderings

Material	Laund. Cycle	Formula I		Formula I - N.B.		Pennwalt's	
		Warp	Fill	Warp	Fill	Warp	Fill
35/65% Polyester/ Cotton Denim Trouser	0 1 5 10	N/A		260 208 190 —	85 79 88 —	260 212 204 209	85 76 88 105
100% Polyester CNT, White Jumper	0 1 5 10			256 245 248 244	210 194 198 210	256 247 244 243	210 192 200 202
50/50 Polyester/ Cotton, White Trouser	0 1 5 10	202 183 171 192	110 105 104 114	202 177 177 188	110 109 102 117	202 182 180 193	110 104 103 107
65/35 Polyester/ Cotton Chambray Shirt	0 1 5 10	N/A		84 82 77 79	60 58 58 55	84 75 — 80	60 56 — 56
100% Polyester/ Cotton Khaki Shirt	0 1 5 10			255 281 287 281	243 208 235 232	255 263 260 277	243 223 214 261
65/35 Polyester/ Cotton White Shirt	0 1 5 10	152 158 — —	68 74 — —	152 154 — —	68 81 — —	152 157 — —	68 83 — —
100% Cotton FRT Chambray Fabric	0 1 5 10	N/A		111 107 95 97	65 59 60 61	111 108 96 —	65 60 63 —
100% Cotton FRT Denim Fabric	0 1 5 10			196 185 172 173	142 137 134 131	196 176 179 176	142 135 135 138

Table 8 - Tensile Strength (lbs.) of Materials
Subjected to Shipboard Launderings (Cont'd)

Material	Laund. Cycle	Formula I		Formula I - N.B		Pennwalt's	
		Warp	Fill	Warp	Fill	Warp	Fill
95/5 Nomex/ Kevlar Blue Fabric	0	N/A		241	150	241	150
	1			231	151	231	154
	5			223	134	219	137
	10			235	151	216	145
65/35 Polyester Cotton White Fabric USNA	0	326	104	326	104	326	104
	1	290	92	289	95	297	92
	5	273	92	289	93	290	93
	10	287	93	284	90	303	93
75/25 Polyester/ Wool Blue Fabric Trouser	0	N/A		152	132	152	132
	1			143	130	145	126
	5			131	114	141	119
	10			144	125	137	121
100% Polyester/ TW/SF Woman's Skirt	0	N/A		353	132	353	153
	1			257	116	251	116
	5			265	131	327	277
	10			265	119	260	116
65/35 Polyester/ Rayon Blue Shirt	0	N/A		146	135	146	135
	1			139	128	142	120
	5			134	126	134	129
	10			141	124	137	121

TW/SF = Texturized Warp/Spun Filling
N.B. = No Bleach

Table 9 - Tear Strength (lbs.) of Materials Subjected to Formula I
With Double the Required Chlorine Bleach

Samples	Initial		Cycle #5		Cycle #15	
	Warp	Fill	Warp	Fill	Warp	Fill
100% Polyester CNT, White Jumper	24	22	18	17	17	16
50/50 Polyester/ Cotton, White Trouser	9	7	12	8	6	5
65/35 Polyester/ Cotton, White Fabric, USNA	No Tear	7	No Tear	6	No Tear	4
65/35 Polyester/ Cotton, White Shirt	7	4	8	5	6	3

Dimensional Stability

The dimensional stability results for each garment/material subjected to the laundry formulas at both locations are presented in Tables 10 and 11. There was virtually no difference noted in dimensional stability under any of the laboratory conditions or test sites.

pH of Laundering Solutions -

The pH of the various laundering formulations was measured at several stages during each of the laundering cycles by NCTRF personnel. Results indicate that during the suds cycle, the pH of Navy Formula I with bleach was 11.1, which is within acceptable limits (10.5 - 11.5). The pH of the Pennwalt product at this stage of the cycle was 10.7, also within acceptable limits. When tested at the sour cycle, however, the pH of the Navy Formula I with bleach was found to be 8.5, which is considered too high. An acceptable limit is in the area of 4 to 5. The pH of the Pennwalt formula at the sour cycle was measured at 5.0. The pH of the Navy Formula I without bleach was not measured.

It was determined that the reason for the high pH of the Navy Formula I at the sour cycle was due to mechanical problems encountered with the shipboard washer which failed to effectively add the sour into the laundry bath. This was verified in the NCTRF laboratory where there was no problem encountered in adding the sour to the laundry bath, resulting in a normal pH of 4.7. All other pH determinations for both products in the NCTRF laboratory were found to be within acceptable limits.

Garment/Material pH After Laundering

The pH of the laundered garment/materials was determined so as to observe the neutralization effectiveness of the sour.

As can be seen in Table 12, the final pH of the laboratory laundered garments/materials with Pennwalt's formulation was found to be nearly the same at all temperatures (120°F, 140°F, 160°F). However, the pH for the fire retardant fabrics with Pennwalt's formulation was found to be higher than those laundered with Formula I without chlorine bleach. A higher pH was also noted for the Navy and Pennwalt formulas aboard ship (Table 13). As mentioned earlier, this is believed to have been caused by the mechanical problems associated with the dispensing of the sour in the final step.

The overall test results for pH indicate that the neutralization effectiveness of the two sours (Pennwalt, Navy) is approximately the same.

Simulated Sea Water Laundering Conditions

This test was performed in an Atlas launder-O-meter, using Instant Ocean (synthetic sea salt) to simulate sea water conditions. Samples were laundered with the Pennwalt formula at a temperature of 140°F.

Table 10 - Effect on Dimensional Stability (%) of Materials Subjected to Laboratory Launderings

Material	Laud. Cycle	Formula I		Formula I NR		Formula I DB		Formula I -Chlorox 2		Pennwalt @120°F		Pennwalt @140°F		Pennwalt @160°F	
		Warp	Fill	Warp	Fill	Warp	Fill	Warp	Fill	Warp	Fill	Warp	Fill	Warp	Fill
100% Polyester COT White Jumper*	1	2.3	-	1.5	-	1.3	0.9	2.8	-	0.0	-	2.6	1.4	2.0	-
	5	2.0	-	2.3	-	2.7	1.4	3.5	-	0.3	-	2.4	1.4	3.0	-
	10	1.8	-	3.0	-	2.5	1.8	2.4	-	2.1	-	-	0.7	2.0	-
65/35 Polyester/ Cotton White Fabric USNA	1	2.2	0.1	2.3	0.2	2.1	0.5	2.0	0.2	1.3	0.2	2.1	-0.5	2.3	0.1
	5	2.8	0.3	2.8	0.2	2.1	0.2	2.4	0.1	2.0	0.3	3.1	-0.5	2.5	0.2
	10	3.2	0.3	3.0	0.2	3.2	0.4	2.6	0.0	1.9	0.1	3.5	-0.6	2.8	0.1
50/50 Polyester/ Cotton White Trousers*	1	2.1	-	1.4	-	1.4	-	0.7	-	2.6	-	1.1	-	1.9	-
	5	3.3	-	1.5	-	1.7	-	2.8	-	3.2	-	1.5	-	2.7	-
	10	2.7	-	3.5	-	2.9	-	2.5	-	4.1	-	2.4	-	3.4	-
65/35 Polyester/ Cotton White Shirt	1	1.5	0.7	N/A	N/A	2.4	1.0	0.6	0.1	1.0	0.2	-	-	N/A	N/A
	5	1.8	-	-	-	2.8	0.8	2.3	0.1	2.2	0.5	1.7	0.4	-	-
	10	1.5	-0.3	-	-	3.9	1.0	1.9	0.1	1.4	0.1	1.0	-0.5	-	-
100% FRT Cotton Denim	1	N/A	N/A	-1.7	0.2	N/A	N/A	N/A	N/A	-2.0	0.6	-2.9	0.7	0.5	0.5
	5	-	-	0.6	1.3	-	-	-	-	2.2	1.4	0.1	0.5	2.2	1.8
	10	-	-	3.0	2.1	-	-	-	-	2.9	1.7	2.3	1.4	3.0	2.2
100% FRT Cotton Chambray	1	N/A	N/A	-0.3	0.0	N/A	N/A	N/A	N/A	1.3	0.6	0.5	0.5	0.1	0.3
	5	-	-	2.0	-	-	-	-	-	2.0	-0.5	2.1	0.1	2.6	-0.6
	10	-	-	-	-	-	-	-	-	3.8	-1.6	3.6	-1.6	4.2	-0.6
35/65 Polyester/ Cotton Denim Trousers*	1	N/A	N/A	2.2	-	N/A	N/A	N/A	N/A	2.0	-	0.4	-	0.1	-
	5	-	-	0.8	-	-	-	-	-	3.4	-	1.2	-	0.7	-
	10	-	-	0.7	-	-	-	-	-	6.8	-	0.4	-	6.4	-

Table 10 - Effect on Dimensional Stability (%) of Materials Subjected to Laboratory Launderings (Cont'd)

Material	Laund. Cycle	Formula I		Formula I WB		Formula I DB		Formula I -Chlorox 2		Pennwalt @120°F		Pennwalt @140°F		Pennwalt @160°F	
		Warp	Fill	Warp	Fill	Warp	Fill	Warp	Fill	Warp	Fill	Warp	Fill	Warp	Fill
65/35 Polyester Cotton Charbray Shirt	1	N/A	N/A	2.1	-	N/A	N/A	N/A	N/A	3.4	-	3.0	-	3.9	1.0
	5			3.7	-					3.9	-	3.5	-	3.9	0.2
	10			4.2	-					4.6	-	3.9	-	4.2	0.2
95/5 Nomex/ Kevlar Blue Fabric	1	N/A	N/A	0.5	0.6	N/A	N/A	N/A	N/A	0.9	0.0	0.5	-0.5	0.5	-0.5
	5			0.9	-0.6					1.7	-0.5	1.5	-0.2	1.0	-1.0
	10			1.5	-0.9					1.9	-1.0	1.9	-0.6	1.2	-1.2
75/25 Polyester/ Wool Blue Fabric	1	N/A	N/A	2.0	0.2	N/A	N/A	N/A	N/A	1.7	0.4	1.8	0.3	2.0	0.4
	5			2.5	0.2					2.4	0.6	2.5	0.7	2.6	0.5
	10			2.6	0.6					2.9	0.9	2.9	1.0	2.5	0.6
100% Polyester TW/SF Woman's Skirt	1	N/A	N/A	1.3	1.3	N/A	N/A	N/A	N/A	1.6	0.5	1.8	-	1.3	1.1
	5			4.8	1.0					2.7	1.0	2.3	0.8	1.7	1.1
	10			1.0	0.6					2.8	1.2	3.1	0.4	1.9	1.1
65/35 Polyester Rayon Blue Shirt	1	N/A	N/A	1.5	2.2	N/A	N/A	N/A	N/A	2.2	1.9	2.5	0.8	2.8	1.9
	5			3.0	2.2					2.2	1.8	2.5	2.3	2.3	2.8
	10			3.8	2.8					2.3	1.9	2.5	2.5	2.5	2.9
100% Polyester COT Khaki Shirt	1	N/A	N/A	1.3	0.7	N/A	N/A	N/A	N/A	1.1	0.3	1.7	0.9	1.1	0.6
	5			1.8	0.3					1.4	0.8	1.8	0.8	1.8	0.8
	10			2.3	0.7					1.1	0.3	1.9	0.5	1.2	1.1

* Garment dimensional stability measured in warp direction only

DB = No Bleach

WB = Double the Required Bleach

TW/SF = Texturized Warp/Spun Filling

Evaluation for soil release was performed initially and after the fourth cycle. Determination of Yellowness and Whiteness Index values was also performed on the laundered samples.

Table 11 - Effect on Dimensional Stability (%) of Materials
Subjected to Shipboard Launderings

Sample Material	Laund. Cycle	Formula I		Formula I - N.B.		Pennwalt's	
		Warp	Fill	Warp	Fill	Warp	Fill
100% Polyester	1	2.3	—	4.5	—	2.9	—
CNT White	5	2.8	—	3.2	—	2.7	—
Jumper*	10	2.8	—	3.1	—	4.3	—
65/35 Polyester/ Cotton White	1	1.8	0.1	2.1	0.2	2.0	0.0
Fabric USNA	5	2.5	0.0	2.8	0.1	2.2	0.0
	10	2.6	0.0	2.9	0.1	2.9	0.2
50/50 Polyester/ Cotton White	1	0.8	—	1.0	—	0.7	—
Trouser*	5	1.8	—	1.8	—	1.6	—
	10	1.8	—	2.3	—	2.5	—
65/35 Polyester/ Cotton White	1	0.5	—	1.0	0.3	—	—
Shirt	5	—	—	—	—	—	—
	10	—	—	0.7	0.1	—	—
100% FRT Cotton	1			2.2	0.7	-1.9	0.4
Denim	5	N/A		1.6	1.3	0.3	1.3
	10			3.2	2.2	2.9	2.1
100% FRT Cotton	1			-0.1	0.9	0.6	0.0
Chambray	5	N/A		3.0	-0.4	3.0	0.0
	10			4.1	-0.3	4.2	-0.3
35/65 Polyester/ Cotton Denim	1			—	—	0.8	—
Trouser*	5	N/A		—	—	1.1	—
	10			—	—	0.8	—
65/35 Polyester/ Cotton Chambray	1			2.1	0.7	3.3	0.0
Shirt	5	N/A		4.1	0.5	—	—
	10			4.2	0.3	4.2	—

Table 11 - Effect on Dimensional Stability (%) of Materials
Subjected to Shipboard Launderings (Cont'd)

Sample Material	Laund. Cycle	Formula I		Formula I - N.B.		Pennwalt's	
		Warp	Fill	Warp	Fill	Warp	Fill
95/5 Nomex/Kevlar Blue Fabric	1			0.6	-0.3	0.8	-0.5
	5	N/A		1.3	-1.0	1.3	-0.8
	10			1.8	-1.0	1.5	-0.7
75/25 Polyester/ Wool Blue Fabric	1			1.5	0.3	1.6	0.3
	5	N/A		2.6	0.7	2.3	0.5
	10			2.7	0.4	2.9	0.5
100% Polyester TW/SF Woman's Skirt	1			1.1	0.7	1.1	0.8
	5	N/A		3.4	0.5	2.0	1.4
	10			4.3	0.4	2.6	1.4
65/36 Polyester/ Rayon Blue Shirt	1			1.3	1.4	2.0	2.1
	5	N/A		2.5	2.2	2.3	2.3
	10			3.5	3.2	2.6	1.2
100% Polyester CNT Khaki Shirt	1			1.8	1.0	1.2	0.5
	5	N/A		1.8	0.9	1.7	1.1
	10			1.9	1.7	—	—

* - Garment dimensional stability measured in warp direction only

N.B. = No Bleach

TW/SF = Texturized Warp/Spun Filling

Note: A reported Negative value signifies elongation in accordance with
Federal Standards 191A.

Table 12 - pH of Materials Subjected to Laboratory Launderings

Material	Laud. Cycle	Formula I	Formula I NR	Formula I DB	Formula I Clorox 2	Pennwalt @ 120°F	Pennwalt @ 140°F	Pennwalt @ 160°F
100% Polyester CNR White Jumper	0	7.1	7.1	7.1	7.1	7.1	7.1	7.1
	1	7.7	6.3	-	6.0	6.9	6.4	6.9
	5	6.2	5.9	6.6	5.9	6.0	6.0	6.2
	10	6.2	6.0	-	5.8	6.3	5.9	6.2
	15	-	-	6.4	-	-	-	-
65/35 Polyester/ Cotton White Fabric USA	0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
	1	6.8	6.0	-	5.7	6.5	6.1	6.2
	5	6.2	6.0	8.4	5.1	5.9	5.9	6.2
	10	6.1	5.5	-	5.0	5.9	5.9	5.8
	15	-	-	7.9	-	-	-	-
50/50 Polyester/ Cotton White Trousers	0	7.3	7.3	7.3	7.3	7.3	7.3	7.3
	1	7.1	6.4	-	5.7	7.0	6.7	7.0
	5	5.9	6.0	6.2	5.3	5.8	5.2	5.7
	10	5.9	6.2	-	5.2	4.4	5.2	6.2
	15	-	-	8.1	-	-	-	-
65/35 Polyester/ Cotton White Shirt	0	7.2	N/A	7.2	7.2	7.2	7.2	N/A
	1	7.5	-	-	5.6	6.7	-	-
	5	5.9	-	7.1	4.8	5.8	5.0	-
	10	5.9	-	-	4.8	5.5	5.4	-
	15	-	-	6.6	-	-	-	-

Table 12 - pH of Materials Subjected to Laboratory Launderings (Cont'd)

Material	Laundering Cycle	Formula I	Formula I NR	Formula I DR	Formula I Clorox 2	Pennwalt @ 120°F	Pennwalt @ 140°F	Pennwalt @ 160°F
100% FRT Cotton Denim Fabric	0	N/A		N/A	N/A	5.9	5.9	5.9
	1					7.2	8.0	7.2
	5					6.4	7.9	7.1
	10					5.2	8.9	7.4
	15					-	-	-
100% FRT Cotton Chambray Fabric	0	N/A		N/A	N/A	5.9	5.9	5.9
	1					6.3	6.6	6.7
	5					5.0	7.4	7.0
	10					4.2	8.5	7.1
	15					-	-	-
35/65 Polyester/Cotton Denim Trousers	0					9.4	9.4	9.4
	1					6.8	7.0	7.9
	5	N/A		N/A	N/A	6.0	6.7	7.5
	10					6.0	8.0	7.0
	15					-	-	-
65/35 Polyester/Cotton Chambray Shirt	0	N/A		N/A	N/A	6.4	6.4	6.4
	1					6.5	6.4	6.5
	5					6.4	6.6	6.7
	10					6.3	6.1	5.4
	15					-	-	-
95/5 Nymex/Kevlar Blue Fabric	0	N/A		N/A	N/A	6.3	6.3	6.3
	1					6.2	5.4	6.8
	5					5.1	6.1	7.4
	10					4.6	8.2	7.8
	15					-	-	-

Table 12 - pH of Materials Subjected to Laboratory Launderings (Cont'd)

Material	Laundering Cycle	Formula I	Formula I N3	Formula I DB	Formula I Clorox 2	Pennwalt @ 120°F	Pennwalt @ 140°F	Pennwalt @ 160°F
75/25 Polyester/ Wool Blue Fabric	0	N/A		N/A	N/A	5.1	5.1	5.1
	1		5.1			7.7	6.7	7.3
	5		7.1			7.1	7.5	6.8
	10		4.6			6.9	5.6	6.8
	15		3.8			-	-	-
100% Polyester/ TW/SF Woman's Skirt	0	N/A		N/A	N/A	7.0	7.0	7.0
	1		7.0			6.5	6.3	8.6
	5		7.4			6.2	6.1	6.1
	10		5.9			6.4	6.2	6.4
	15		5.8			-	-	-
65/35% Polyester/ Rayon Blue Shirt	0	N/A		N/A	N/A	6.0	6.0	6.0
	1		6.0			7.7	7.0	8.3
	5		7.6			7.4	7.0	7.4
	10		6.1			6.7	8.2	6.5
	15		6.0			-	-	-
100% Polyester CNT Khaki Shirt	0	N/A		N/A	N/A	5.7	5.7	5.7
	1		5.7			6.3	6.0	5.2
	5		6.4			6.1	6.2	6.2
	10		6.1			6.1	5.8	6.2
	15		5.7			-	-	-

N3 = No Bleach

DB = Double the Required Bleach

TW/SF = Texturized Warp/Spun Filling

Table 13 - pH of Materials Subjected to Shipboard Laundering

Material	Laund. Cycle	Formula I	Formula I W/O Bleach	Pennwalt @ 160°F
100% Polyester	0	7.1	7.1	7.1
CNT White Jumper	1	7.3	9.1	7.3
	5	8.6	7.2	6.1
	10	7.1	6.4	6.8
65/35 Polyester/ Cotton, White	0	6.0	6.0	6.0
Fabric USNA	1	8.0	9.0	8.1
	5	9.4	7.2	5.9
	10	8.9	7.2	5.9
50/50 Polyester/ Cotton, White	0	7.2	7.3	7.3
Trouser	1	8.1	9.7	8.9
	5	9.2	7.9	5.1
	10	9.2	7.5	6.0
65/35 Polyester/ Cotton, White	0	7.2	7.2	7.2
Shirt	1	—	—	—
	5	—	—	—
	10	8.2	9.5	7.5
100% FRT Cotton	0		5.9	5.9
Denim	1	N/A	7.4	7.8
	5		8.7	7.4
	10		6.5	7.9
100% FR Cotton	0		5.9	5.9
Chambray	1	N/A	7.1	7.5
	5		8.3	7.4
	10		5.8	7.9
35/65 Polyester/ Cotton Denim	0		9.4	9.4
Trouser	1	N/A	7.9	9.3
	5		9.4	7.4
	10		—	8.6
65/35 Polyester/ Cotton Chambray	0		6.4	6.4
Shirt	1	N/A	7.0	7.6
	5		9.3	—
	10		5.9	7.4
95/5 Nomex/Kevlar	0		6.3	6.3
Blue Fabric	1	N/A	6.4	9.1
	5		8.6	7.2
	10		5.7	7.8

Table 13 - pH of Materials Subjected to Shipboard Laundering (cont'd)

Material	Laund. Cycle	Formula I	Formula I W/O Bleach	Pennwalt @ 160°F
75/25 Polyester/ Wool Blue Fabric	0	N/A	5.1	5.1
	1		7.6	8.9
	5		9.2	7.2
	10		6.0	8.2
100% Polyester TW/SF Woman's Skirt	0	N/A	7.0	7.0
	1		6.4	8.4
	5		8.4	6.1
	10		6.1	6.7
65/35 Polyester/ Rayon Blue Shirt	0	N/A	6.0	6.0
	1		7.4	9.3
	5		9.2	7.7
	10		5.7	8.6
100% Polyester CNT Khaki Shirt	0	N/A	5.7	5.7
	1		5.9	6.7
	5		7.6	6.1
	10		5.2	6.4

Test results for these samples revealed a slight decrease in soil release ratings as well as a higher Yellowness and Whiteness Index differential when compared to samples laundered in fresh water. It must be noted, however, that a laboratory test is not fully representative of actual conditions. To confirm these results would require a full scale shipboard test.

Water Hardness -

The hardness of the water in the shipboard laundry was found to be extremely high (393 ppm) while hardness of the water in the laboratory was 50 ppm. This difference in hardness between shipboard and laboratory laundries seemed to have little effect on test results.

Cost Analysis -

The following is a breakdown of the estimated cost per load for each of the formulations used in this study.

1. Navy Formula I with chlorine bleach..... \$0.87/100 lbs.
2. Navy Formula I without chlorine bleach..... \$0.77/100 lbs.
3. Pennwalt's Formula with sour/conditioner..... \$1.00-1.25/100 lbs.*

* Pennwalt estimate.

Based on the above figures it can be seen that use of the Pennwalt formula results in an increase of between 13 and 48 cents per load over Navy Formula I.

CONCLUSIONS

Test results indicate that the present Navy formulas and Pennwalt's formula have similar cleaning capabilities and anti-bacteria protection, with a slight edge going to the Pennwalt formula. The only real differences observed seem to be in the areas of user efficiency and cost per load, with the Pennwalt system having the advantage for the former and the Navy formulas holding the advantage for the latter. The Pennwalt formula also provides an advantage in the form of utilization of less storage space aboard ship as well as less chance for spoilage.

Pennwalt Corporation test results, based on shipboard laundering of their own test swatches aboard the USS RANGER, appear to validate our findings. Pennwalt's results are attached as Appendix F.

RECOMMENDATIONS

Based on overall results, it is recommended that a performance specification be prepared describing requirements derived from the properties of the Pennwalt formulation. The specified laundry formula would be limited to two products: 1. a "one shot" detergent which would include a non-chlorine bleach 2. a combination sour/bacteriostat. The performance specification would also include requirements for type and dimensions of containers in which the laundry products would be packaged for shipment and storage. This recommendation is based on the following facts: a. the Pennwalt formula performs at least as good as the Navy formulation in all respects b. the Pennwalt formulation provides several benefits, including the use of two additives as opposed to five, the use of non-chlorine bleach and the reduction of storage space by 55%.

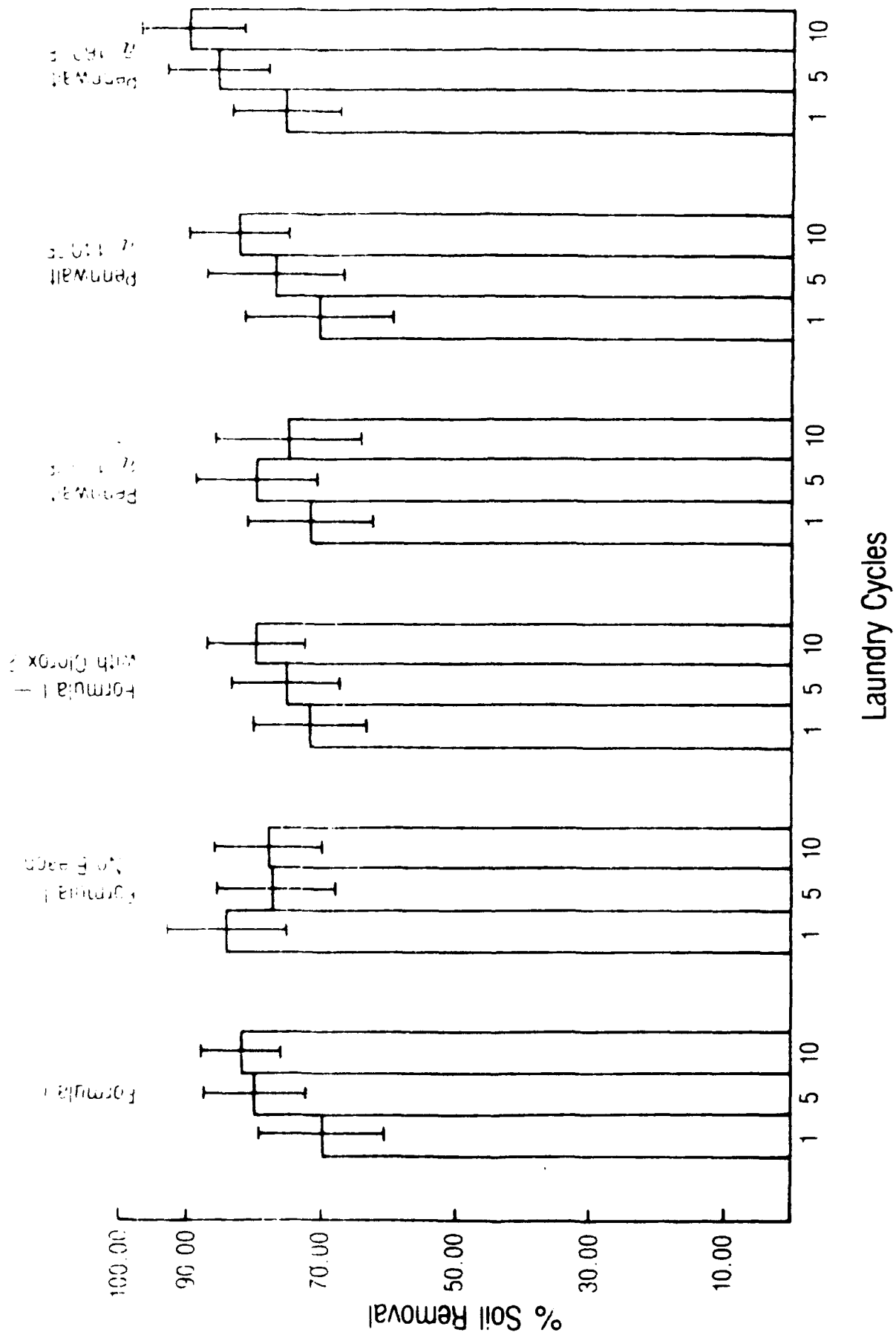


Figure 1. Soil Removal Effectiveness During Laboratory Launderings — White Materials

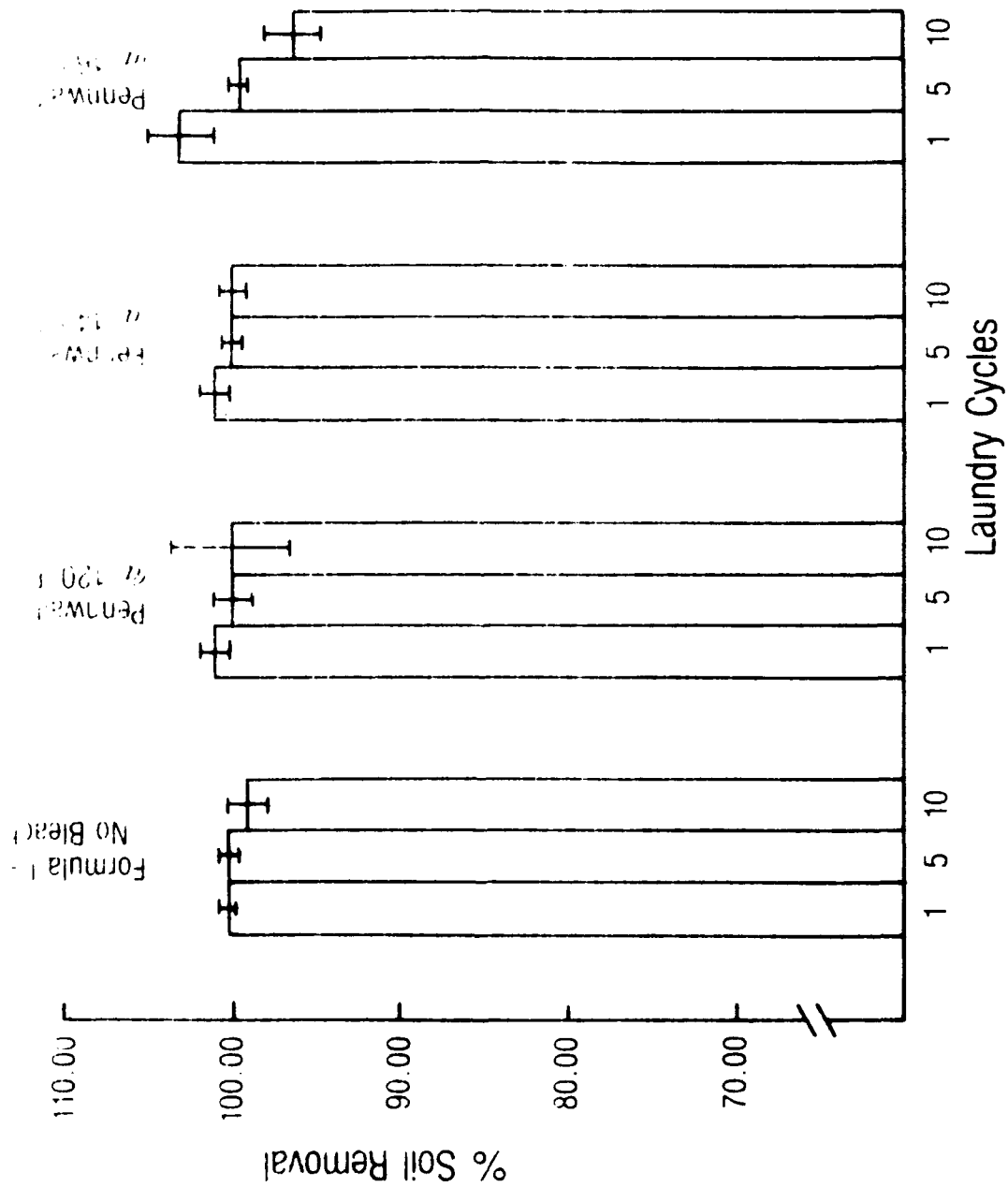


Figure 2. Soil Removal Effectiveness During Laboratory Launderings —Blue Materials

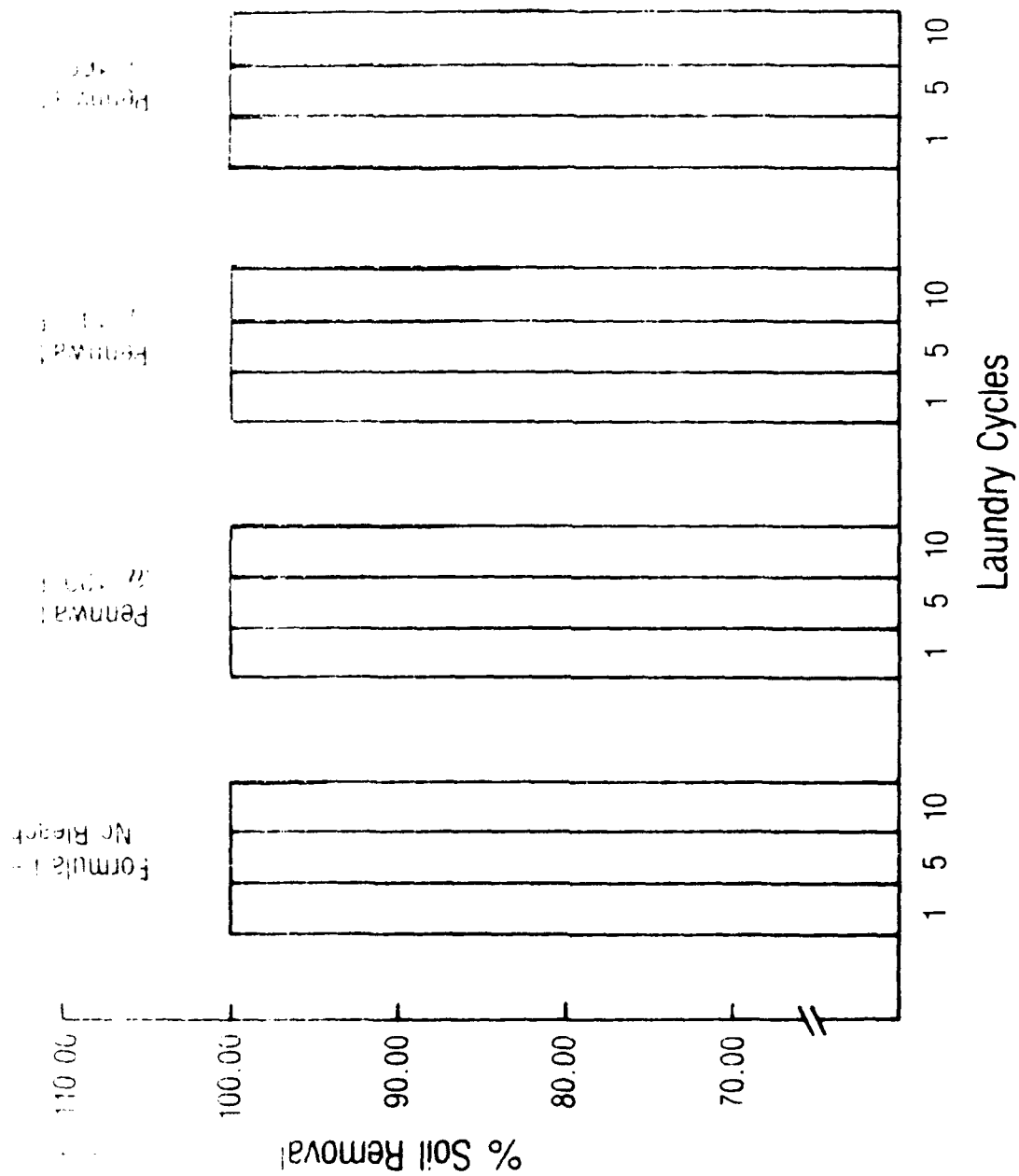


Figure 3. Soil Removal Effectiveness During Laboratory Launderings — Khaki Materials

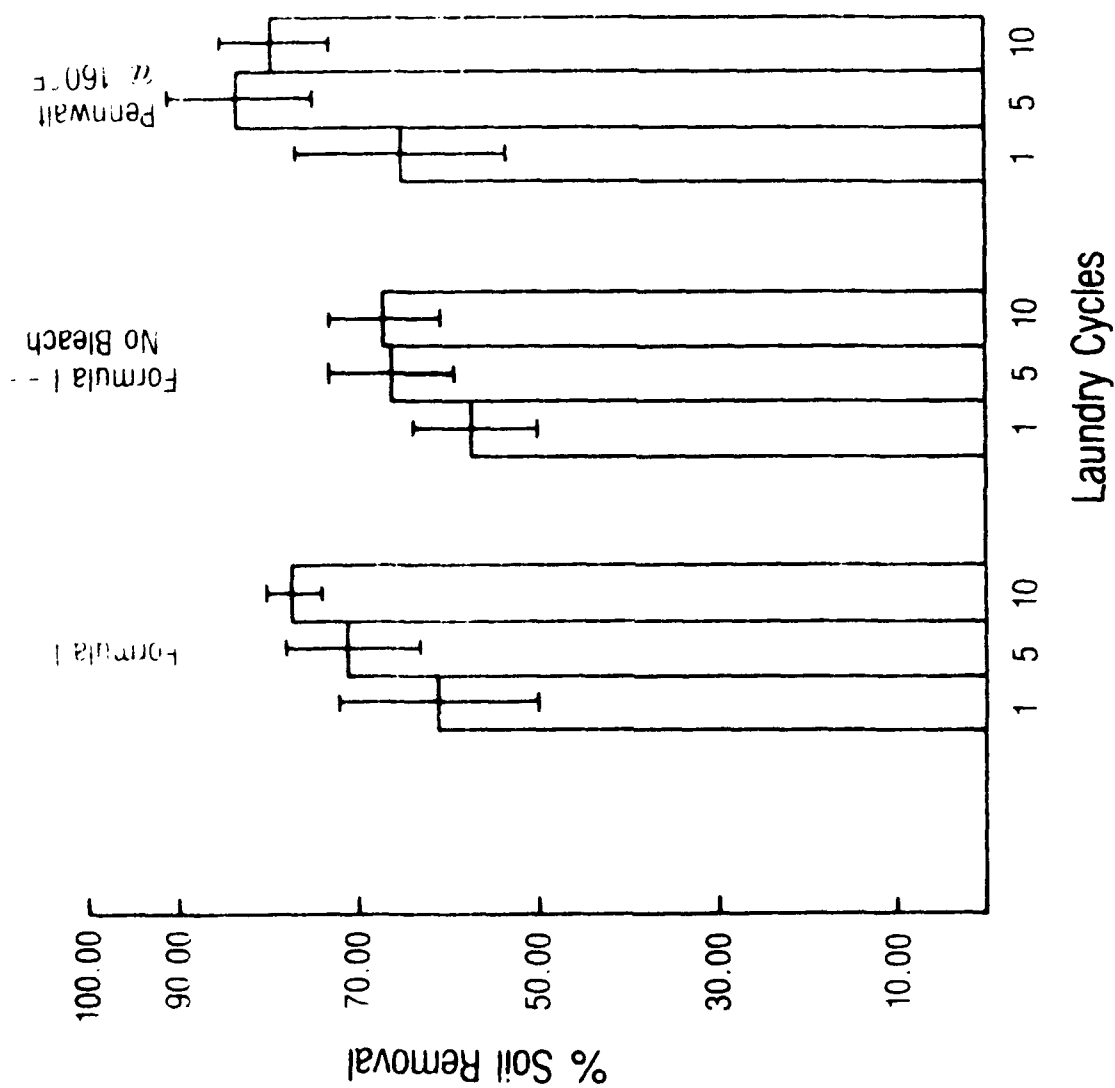


Figure 4. Soil Removal Effectiveness During Shipboard Launderings of White Materials

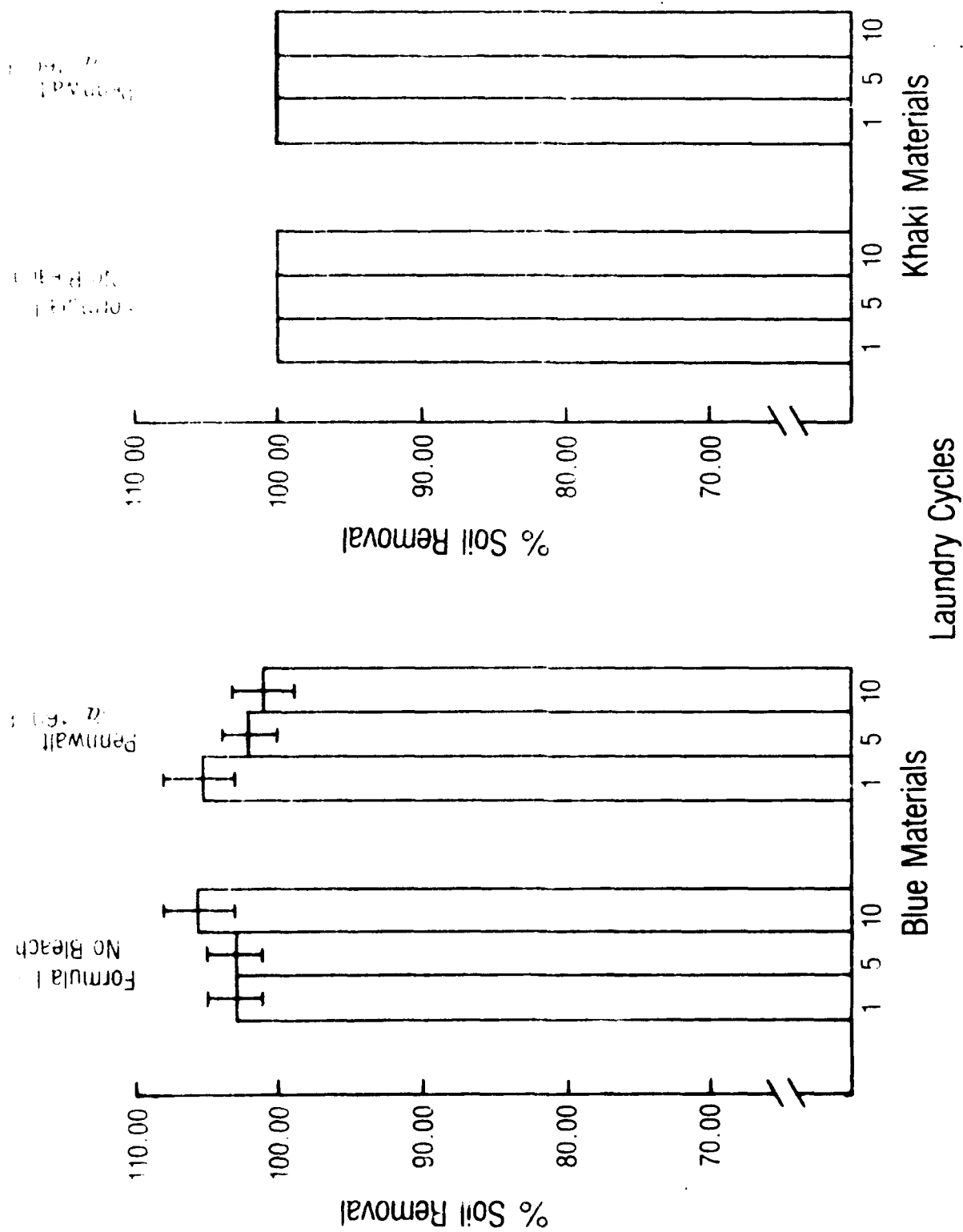


Figure 5. Soil Removal Effectiveness During Shipboard Launderings of Blue and Khaki Materials

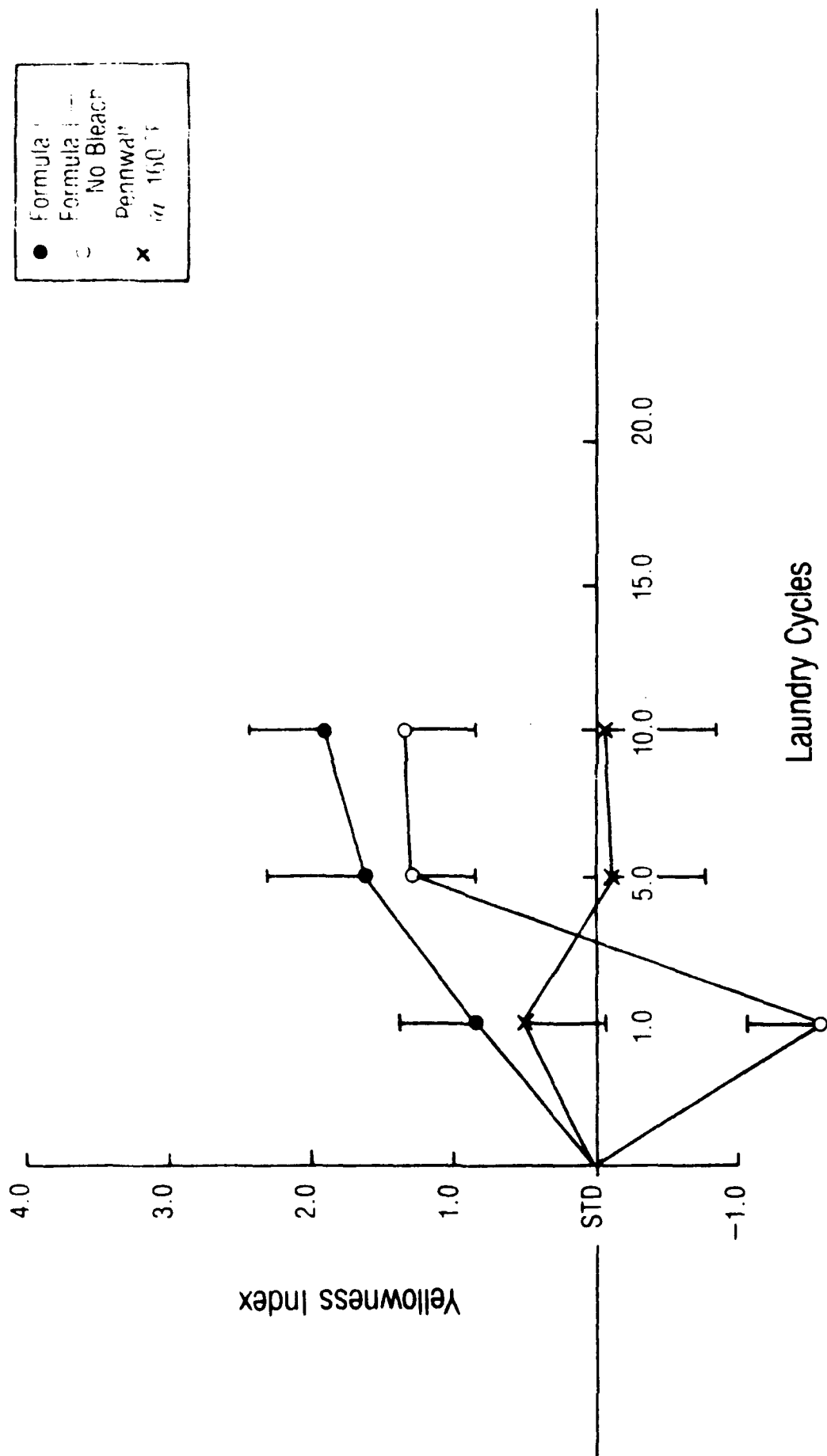


Figure 6. Average Yellowness Index for Shipboard Launderings

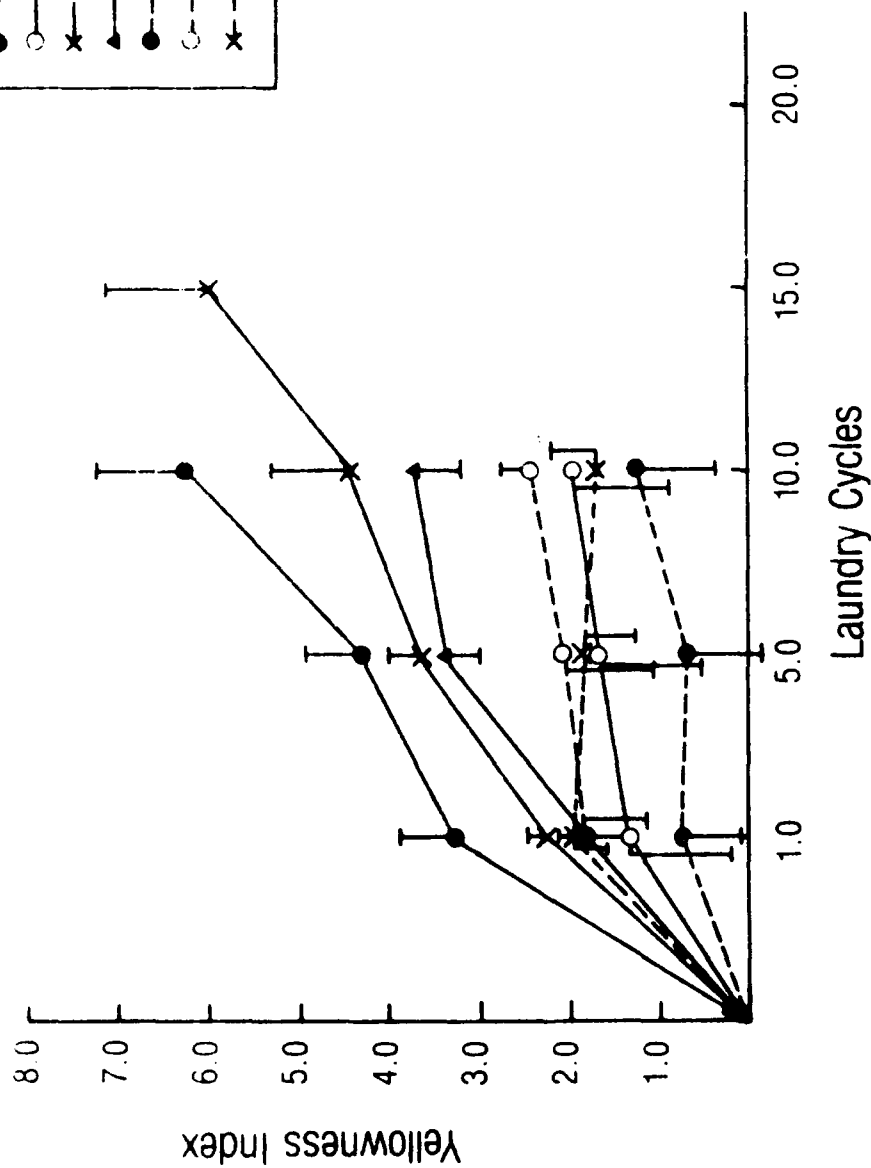
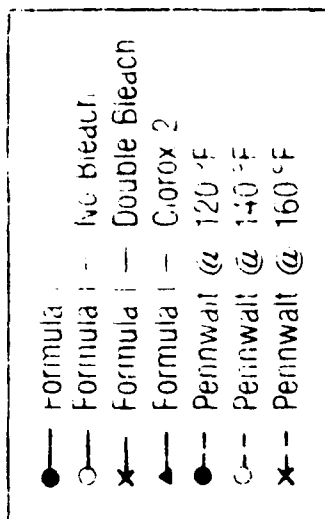


Figure 7. Average Yellowness Index for Laboratory Launderings

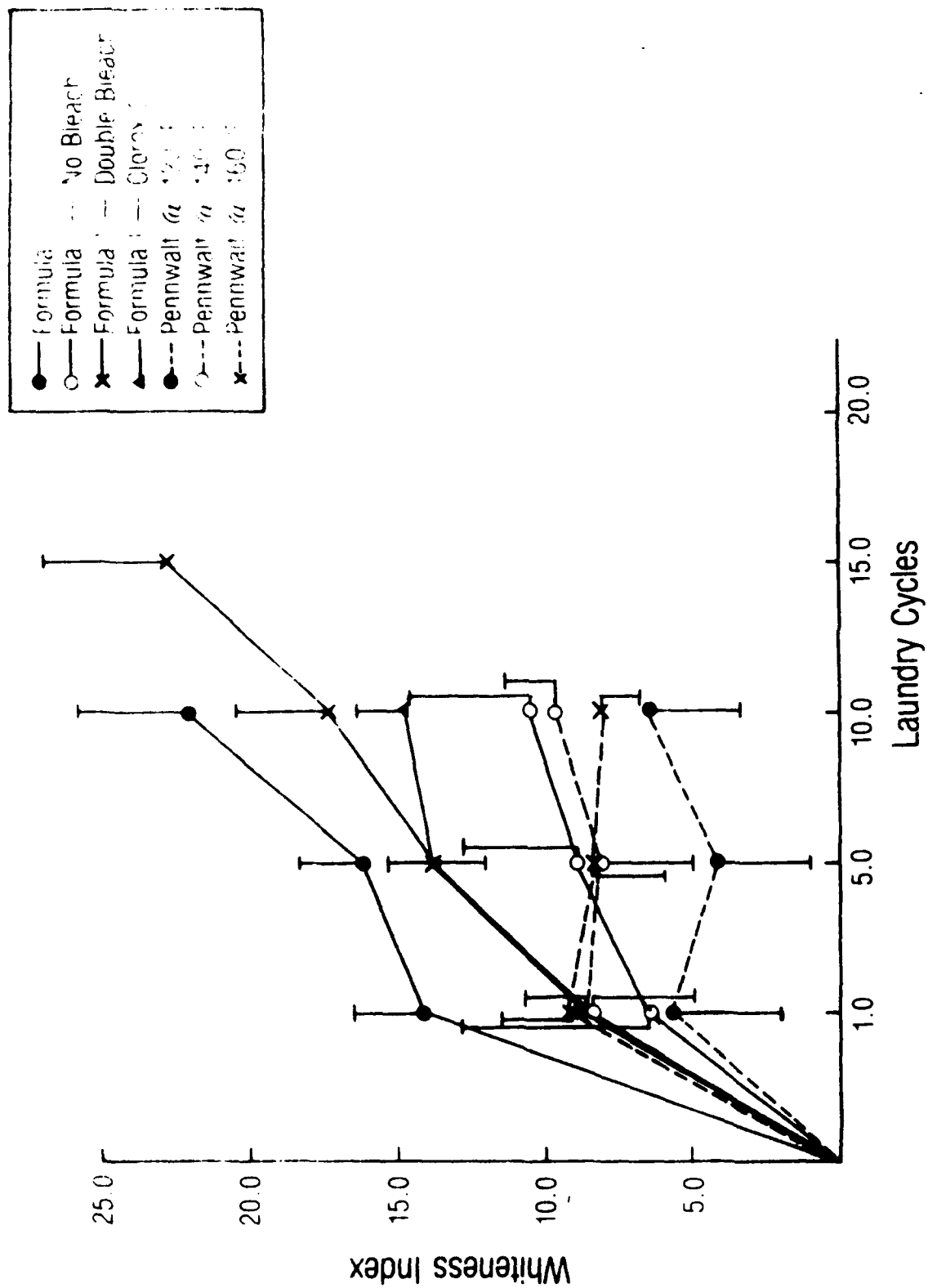


Figure 8. Average Whiteness Index for Laboratory Launderings

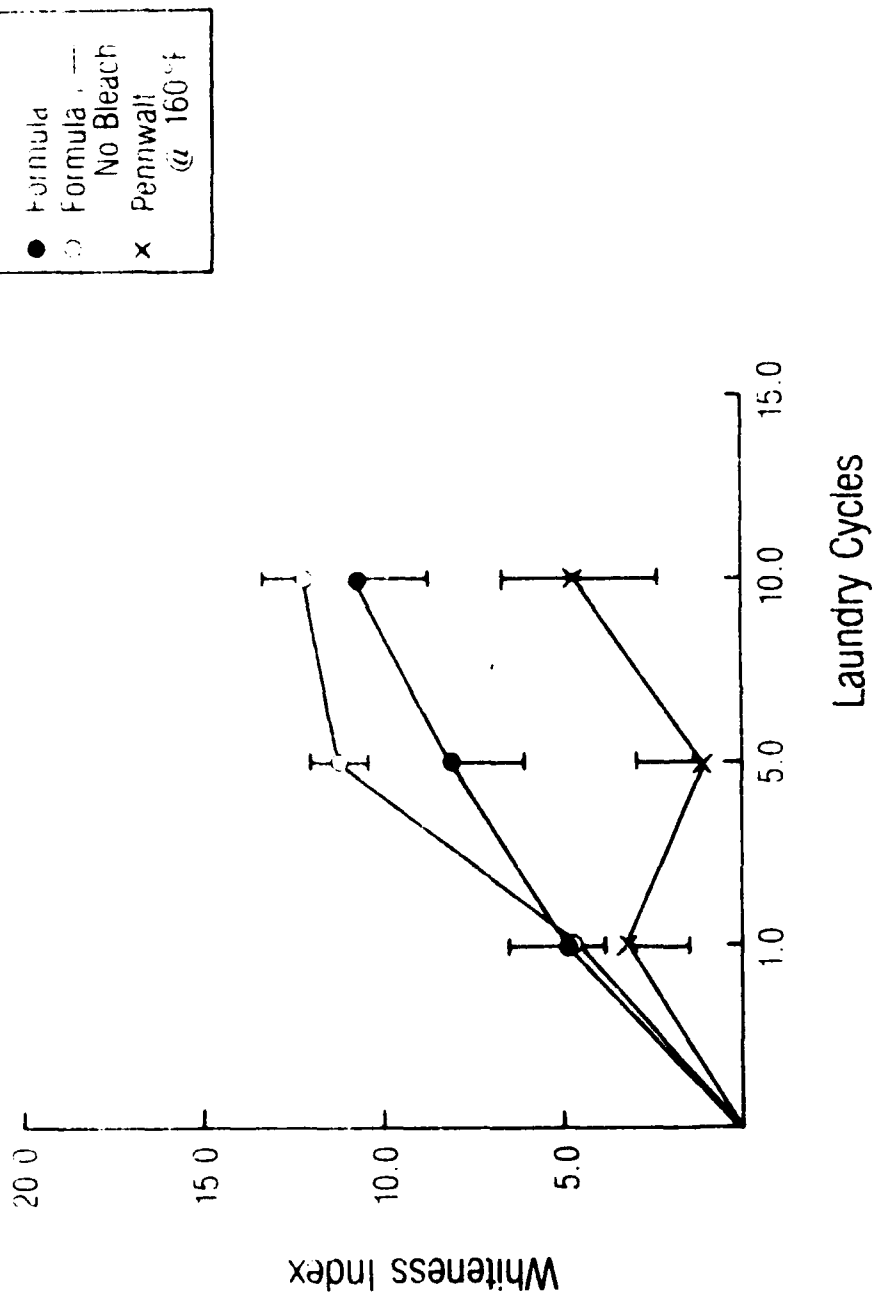


Figure 9. Average Whiteness Index for Shipboard Launderings

- Formula 1 — No Bleach
- Pennwalt @ 120°F
- ▲ Pennwalt @ 140°F
- × Pennwalt @ 160°F

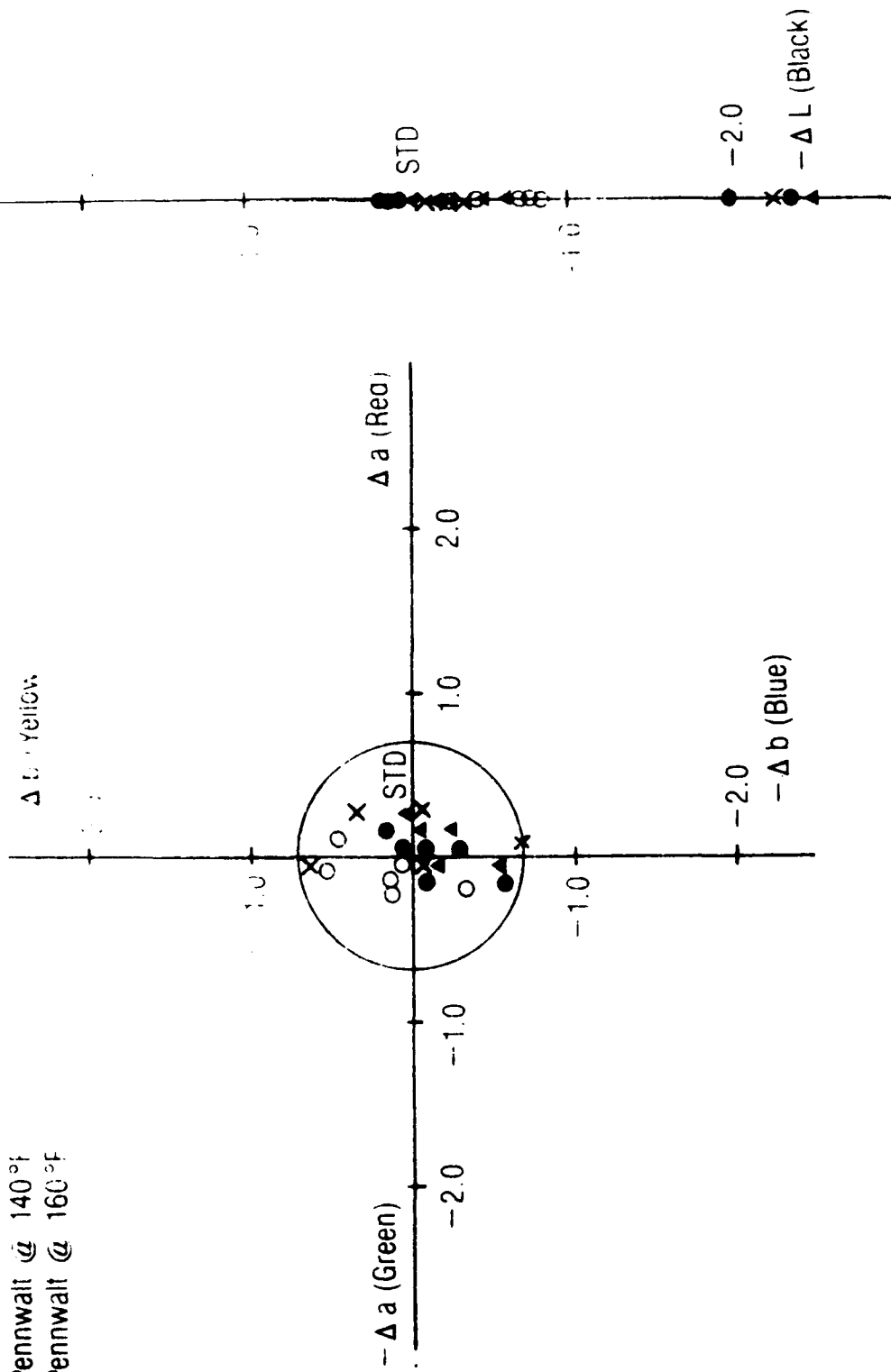


Figure 10. Average CIE Lab Color Difference for Laboratory Launderings —
Blue and Khaki Materials

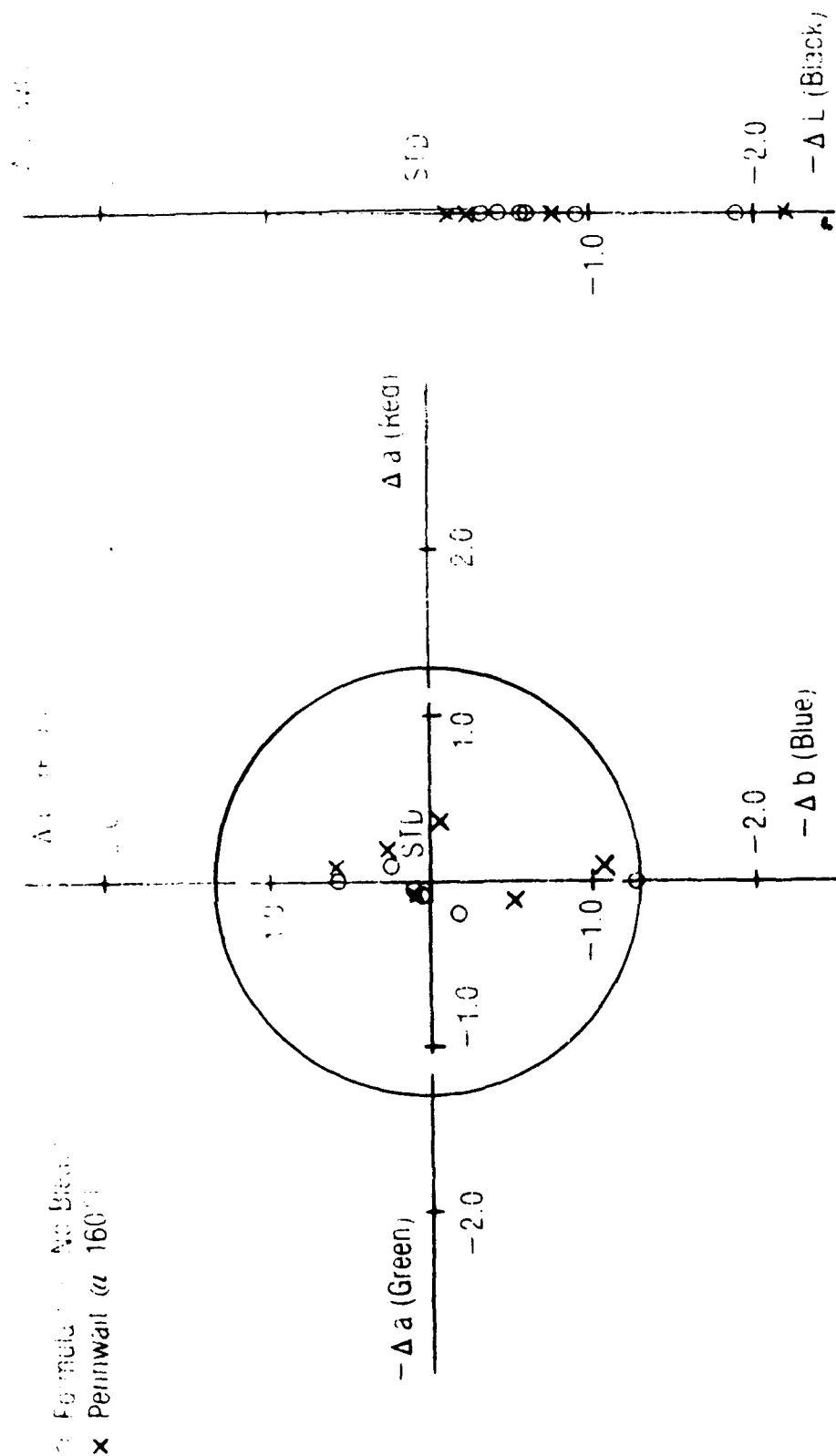


Figure 11. Average CIE Lab Color Difference for Shipboard Launderings — Blue and Khaki Materials

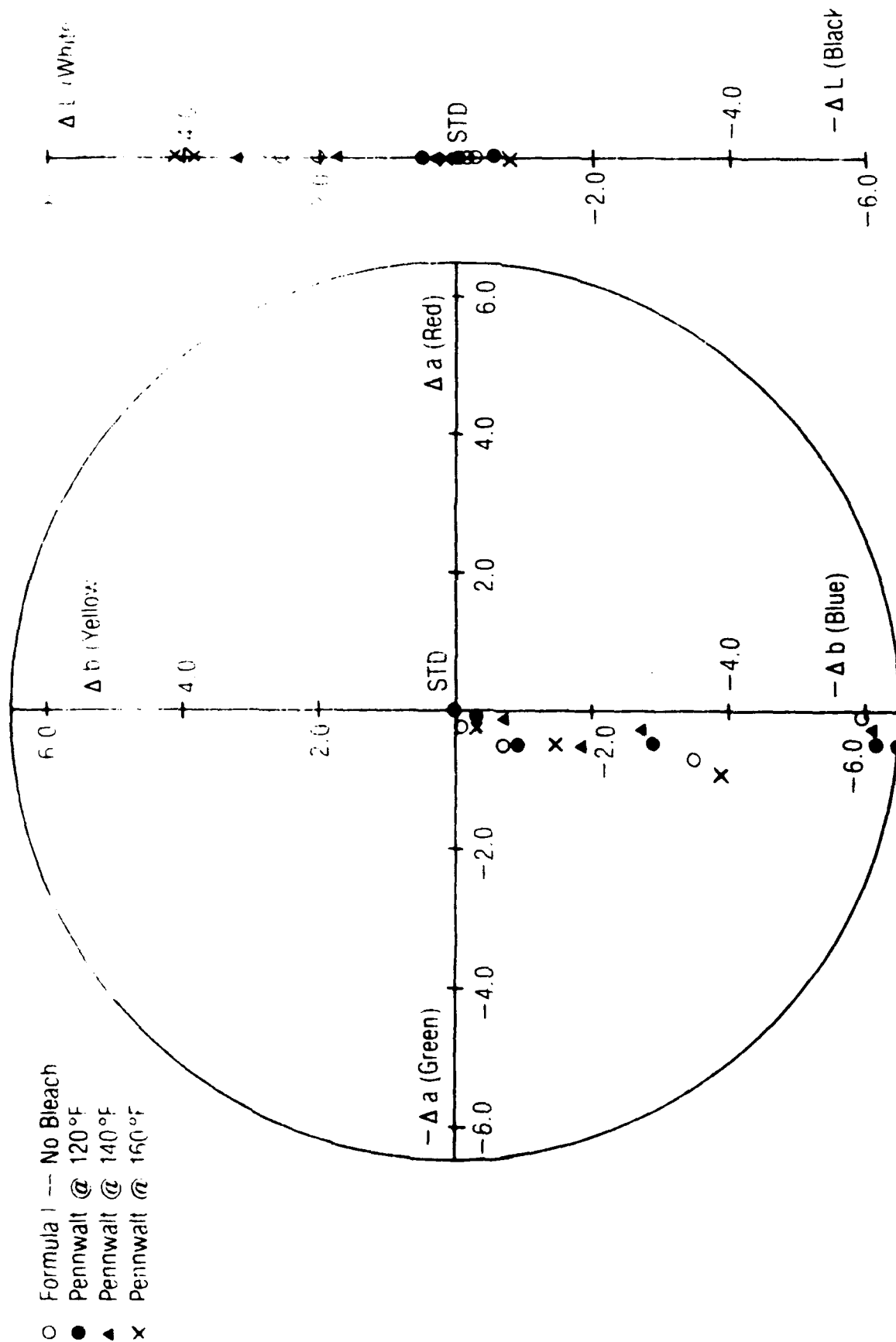


Figure 12. Average CIE Lab Color Difference for Laboratory Launderings — Utility Uniform

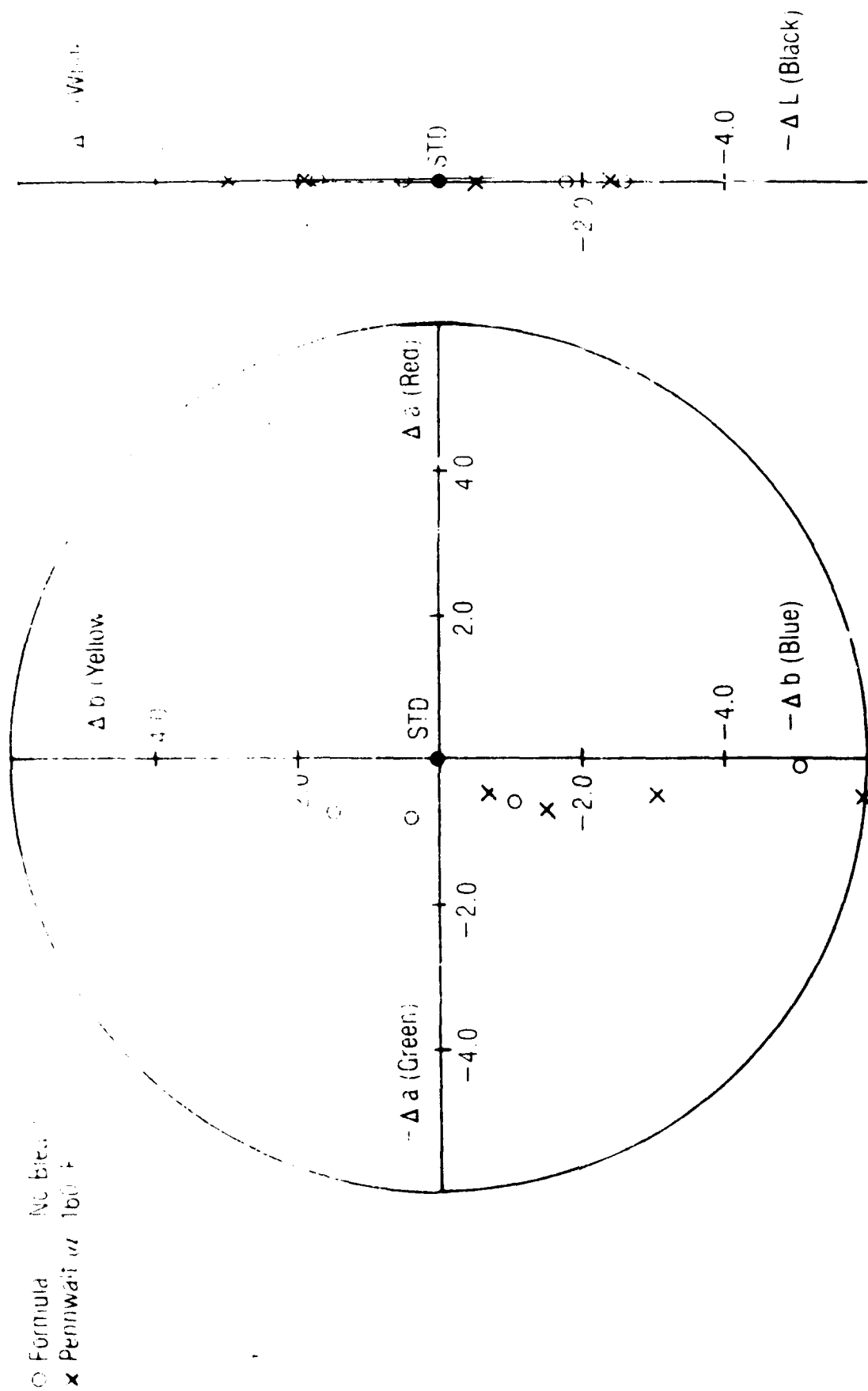


Figure 13. Average CIE Lab Color Difference for Shipboard Launderings — Utility Uniform

APPENDIX A
NAVY FORMULA I
HIGH TEMPERATURE FORMULA WITH BLEACH

CLASSIFICATION: Cotton, Cotton/Synthetic Blends of White and Fast Colors
P-D-245-C Detergent
Soft/Hard Water - Type I
Sea Water - Type II

STEP	NOTES	OPERATION	CYCLE TIME (MINUTES)	WATER TEMP. (°F)	WATER LEVEL	SUPPLIES 100 LB LOAD BASIS
1	A	Break/Suds	10	160	4"	8 oz. detergent 16 oz. alkali 2 oz. non-ionic
2		Drain	1			
3		Bleach	6	160	4"	2 oz. dry organic bleach
4		Drain	1			
5		Spin	1			
6		Rinse	3	160	4"	
7		Drain	1			
8		Rinse	3	160	4"	
9		Drain	1			
10	B/C	Sour	4	130	4"	2 oz. sour blue 12 oz. instant starch
11		Drain	1			
12		Final Spin	4			

- A. Add non-ionic while water is being added.
B. Bacteriostats are added in this operation, if required.
C. Add starch and run for 10 minutes in the manual mode when starch is required.

FOR SEA WATER WASHING

1. Use P-D-245C Detergent Type II in place of alkali (16 oz/100 lb load)
2. Eliminate use of bleach in Step 3. Use as a flush if necessary on dirty load.
3. Use fresh water in steps 6, 8, 10.

APPENDIX B
NAVY FORMULA II
HOT FORMULA WITHOUT BLEACH

CLASSIFICATION: Cotton, Synthetic Blend Colored-Khaki, Dungaree, etc.

P-D-245-C Detergent

Hard/Soft Water - Type I

Sea Water - Type II

STEP	NOTES	OPERATION	CYCLE TIME (MINUTES)	WATER TEMP. (°F)	WATER LEVEL	SUPPLIES 100 LB LOAD BASIS
1	A	Break/Suds	10	140	4"	8 oz. detergent 16 oz. alkali 2 oz. non-ionic
2		Drain	1			
3		Flush/Suds	6	140	4"	
4		Drain	1			
5		Spin	1			
6		Rinse	3	140	4"	
7		Drain	1			
8		Rinse	3	140	4"	
9		Drain	1			
10	B/C	Sour	4	120	4"	2 oz. sour blue 12 oz. instant starch
11		Drain	1			
12		Final Spin	4			

A. Add non-ionic while water is being added.

B. Bacteriostats are added in this operation, if required.

C. Add starch and run for 10 minutes in the manual mode when starch is required.

FOR SEA WATER WASHING

Use sea water in steps 1, 3. Use Type II Detergent

Use fresh water in steps 6, 8, 10.

APPENDIX C
PENNWALT'S LAUNDRY FORMULA

CLASSIFICATION: FRT Cotton, Cotton/Synthetic Blends of White and all colors

STEP	OPERATION	CYCLE TIME (MINUTES)	WATER TEMP. (°F)	WATER LEVEL	SUPPLIES 100 LB LOAD BASIS
1	Break/Suds	10	160	4"	16 oz. of Pennwalt N-Det-2
2	Drain	1			
3	Flush/Suds	6	160	4"	
4	Drain	1			
5	Spin	1			
6	Rinse	3	160	4"	
7	Drain	1			
8	Rinse	3	160	4"	
9	Drain	1			
10	Sour/Bact.	4	130	4"	1.5 oz Sour/Bacteriostat
11	Drain	1			
12	Final Spin	4			

APPENDIX D



United States Testing Company, Inc.

Biological Services Division

115 PARK AVENUE • HOBOKEN NEW JERSEY 07030 • 201-792 2400

REPORT OF TEST

Analysis of Bacteriostatic
and Related Properties of
Two Laundry Detergent Formulas

Conducted for:

Navy Clothing & Textile Research Facility
21 Strathmore Road
Natick, MA 01760

TEST REPORT NO. 05498

SIGNED FOR THE COMPANY

BY

Oliver Shapiro
Microbiologist

Daniel Drozdowski
Mgr, Biological Services Div.

Laboratories in: New York • Chicago • Los Angeles • Houston • Tulsa • Memphis • Reading • Richland

THIS REPORT APPLIES ONLY TO THE STANDARDS OR PROCEDURES IDENTIFIED AND TO THE SAMPLE(S) TESTED. THE TEST RESULTS ARE NOT NECESSARILY INDICATIVE OR REPRESENTATIVE OF THE QUALITIES OF THE LOT FROM WHICH THE SAMPLE WAS TAKEN OR OF APPARENTLY IDENTICAL OR SIMILAR PRODUCTS. NOTHING CONTAINED IN THIS REPORT SHALL MEAN THAT UNITED STATES TESTING COMPANY, INC. CONDUCTS ANY QUALITY CONTROL PROGRAM FOR THE CLIENT TO WHOM THIS TEST REPORT IS ISSUED UNLESS SPECIFICALLY SPECIFIED. OUR REPORTS AND LETTERS ARE FOR THE EXCLUSIVE USE OF THE CLIENT TO WHOM THEY ARE ADDRESSED, AND THEY AND THE NAME OF THE UNITED STATES TESTING COMPANY, INC. OR ITS SEALS OR INSIGNIA ARE NOT TO BE USED UNDER ANY CIRCUMSTANCES IN ADVERTISING TO THE GENERAL PUBLIC AND MAY NOT BE USED IN ANY OTHER MANNER WITHOUT OUR PRIOR WRITTEN APPROVAL. SAMPLES NOT DESTROYED IN TESTING ARE RETAINED A MAXIMUM OF THIRTY DAYS.

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Navy Clothing & Textile Research Facility
21 Strathmore Road
Natick, Massachusetts 01760

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Laundry formulation chemicals and samples of test laundry were submitted by the Client, and identified as follows.

Chemicals: A. Navy Formula I

1. Detergent
2. Alkali
3. Non-ionic
4. Dry organic bleach
5. Sour blue

B. Pennwalt's Laundry Formula

1. Pennwalt's N-DET-2
2. Sour/conditioner

- Test laundry:
1. White towels (T)
 2. Black socks (SB)
 3. White socks (SW)
 4. Men's shorts (BS)
 5. Men's briefs (BR)

Project: Analysis of Bacteriostatic and Related Properties of the submitted formulas.

Test Dates: 8/29/85 - 10/3/85

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Procedures:**A. Laundry cycles**

Washing cycles were performed on the test fabric, using a Najort Washer (Robert Ewing & Sons, Troy, N.Y.). The types and amounts of the laundry additives were as specified by the Client (see Tables 1 and 2).

For each cycle, one of each of the test items was included in the load, and the load was filled to a total of 10 pounds with miscellaneous untreated cotton fabric. The amounts of each chemical additive, specified as the number of ounces per 100 pounds, were adjusted accordingly; i.e., one-tenth of that amount was added.

The times, temperatures and additives used at each step were in conformance with those specified in Tables 1 and 2.

All wash fabrics were dried in a Sears Kenmore dryer, at a temperature of 170°F. Each wash load was dried separately.

B. Examination of Wash Water

At the beginning of each Break/Suds cycle portion, the following was added, in addition to the required laundry chemicals.

- i. 20, 40 or 80 grams of organic material, in the form of active laboratory topsoil.
2. Approximately 3×10^9 colony forming units of each of Staphylococcus aureus (ATCC #5638) and Escherichia coli (ATCC #4352) also known as Klebsiella pneumoniae.
Note: the garden soil was also assumed to have some level of residential microbial population.

At the conclusion of the Break/Suds cycle portion, three mls were removed and placed in bacteriological tubes containing Lethen broth. These tubes were maintained in ice water, or refrigerated, until the commencement of testing, in order to prevent any propagation of microorganisms (giving falsely high counts).

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Examination of Wash Water (continued)

Microbial counts were determined by plating the inoculated Lethen broth in Nutrient Agar in dilutions of 0 (undiluted), 1/10, 1/100 and 1/1000. These plates were incubated at 37°C (approx. 98.6°F) for 48 hours, and resultant colonies were counted.

C. Petrocci-Clark Antimicrobial Fabric Test

Molten Nutrient Agar was prepared, and kept in liquid form until use. Just prior to plate preparation, one ml. of a 24-hr culture of S. aureus for every 100 ml of molten agar was inoculated into the agar and this inoculated agar was poured into sterile Petri dishes. After the agar hardened, a 2"x2" square of the test fabric was pressed firmly onto the surface of the agar, and these were then incubated at 37°C for 48 hours. This technique was conducted using K. pneumoniae as well.

D. AATCC-100

This methodology conforms with that specified by the American Association of Textile Chemists and Colorists. Both untreated fabric and the test fabrics are exposed to 24-hour cultures of S. aureus and K. pneumoniae, after which time the samples and control are rinsed with sterile broth, and plate counted as in Procedure B.

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E. A.O.A.C. Germicidal Equivalency Test

This procedure was conducted in accordance with those specified in the Official Methods of Analysis of the Association of Organic and Analytical Chemists, 13th edition, 1980.

Chlorine standards, of 200 ppm, 100 ppm and 50 ppm are prepared, as well as test concentrations of the two sample formulas. Each of these is tested by the following.

Fifty ul of a 24-hour culture of S. aureus is inoculated into the test concentration, and 1 minute later a loopful of the inoculated test concentration is transferred into 10 ml of sterile Letheen broth. After an additional 30 sec., another 50 ul of the bacterial culture is inoculated into the same test concentration. Sixty seconds later, or 2.5 minutes into the test, a loopful is transferred into a second subculture tube containing 10 ml sterile Letheen broth. This cycle is repeated until 10 subculture tubes have been inoculated. Each series of 10 subcultures (one series for each of the chlorine standards and test concentrations) is then incubated for 48 hours at 37°C. After this time the tubes are observed for growth (turbidity) or no growth.

Phenol Resistance was also run, as a check on the bacterial culture's resistance.

F. A.O.A.C. Sanitizer Test

This procedure was conducted in accordance with those specified in the Official Methods of Analysis of the Association of Organic and Analytical Chemists, 13th edition, 1980.

Two flasks, containing 99 ml of the test solution, are prepared. An additional flask with 99 ml sterile saline is also prepared as a control. One ml of a 48-hour culture of Staphylococcus aureus (ATCC #6538) is added to the flask while the flask's contents are swirled by the operator. One-ml portions are added to Letheen broth 30 and 60 seconds after the addition of the culture. The broths are then diluted and plate-counted, as in Procedure B: Examination of Wash Water.

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G. Breaking Strength

Breaking strengths of 50/50 blends of natural and synthetic fiber-containing materials (terry cloth towels) were conducted on unwashed samples and samples from each of the wash treatments using PTMS 191A, Method 5100. Breaking strengths of 85/15 blends of natural/synthetic fiber-containing material (boxer-style men's shorts) were conducted in a similar fashion.

H. Primary Skin Irritation Test

From each of the test cycles, one fabric was selected at random (using computer-generated randomization) for testing. Each sample was then tested as follows.

The test was conducted in accordance with the procedures of the Federal Hazardous Substances Act, as outlined in the Code of Federal Regulations, Title 16, Chapter IIc, paragraph 1500.41.

Six New Zealand Strain Albino rabbits are selected for the test. The hair is clipped from the back and flank of the animal. Patches (2.5cm x 2.5cm) of surgical gauze are applied to the abraded and unabraded area of the skin by using thin bands of mild adhesive tape.

- i) Portions of 0.5 mls of the submitted sample are introduced under each of the patches in case of liquids.
- ii) 0.5g of the submitted sample are introduced under each of the patches in case of solids. Solids are moistened or dissolved in an appropriate solvent.

The trunks of the rabbits are then wrapped with rubberized cloth (or other neutral impervious material) to hold the patches in position and to retard evaporation of any volatile substances during the 24 hour exposure period. Upon removal of the patches, the resulting skin reactions are evaluated. Readings are also taken after 72 hours. The primary irritation score is derived by addition of each individual score and dividing the total score by 4. For the evaluation, the following rating scale is used.

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Primary Skin Irritation Test (continued)

The combined average of primary irritation index is evaluated on the basis of a scale weighted scores as follows:

i. Erythema and Eshcar Formation

No erythema	0
Very slight erythema (barely perceptible)	1
Well defined erythema	2
Moderate to severe erythema	3
Severe erythema (beet redness) to slight eschar formation (injuries in depth)	4
Total possible erythema score	4

ii. Edema Formation

No edema	0
Very slight edema (barely perceptible).	1
Slight edema (edges of area well defined by definite raising)	2
Moderate edema (area raised approximately 1mm).	3
Severe edema (raised more than 1mm and extending beyond area of exposure).	4
Total possible edema score	4
Total possible score for primary irritation	8

I. Aesthetic Evaluation

Samples of each of the laundry cycle results were inspected by a panel of five testers for appearance, feel and smell of the items.

Results

A. Examination of Wash Water

The table below summarizes the recovered bacterial growth from the wash waters, at the completion of Break/Suds cycle.

	<u>Colony Forming Units/ml</u> <u>Amount of Organic Carbon Added</u>		
	<u>20g</u>	<u>40g</u>	<u>80g</u>
Pennwalt's Formula	1355	1950	2350
Navy Formula 1	430	1610	2020

As a control, the wash waters were sampled shortly (approx. 10 seconds) after the addition of the inoculum. The average count obtained from these was 6.1×10^5 colony forming units/ml.

B. Petrocci-Clark Antimicrobial Fabric Test

The table below summarized the results obtained from this test.

<u>Sample</u>	<u>Zone of Inhibition (mm)</u>	
	<u>S. aureus</u>	<u>E. coli</u>
1a ^{Tb}	0/0 ^c	0/0
1 SB	0/0 ^c	0/0
1 SW	0/0 ^c	0/0
1 BR	0/0 ^c	0/0
1 BS	0/0 ^c	0/0
2 T	0/0 ^c	0/0
2 SB	0/0 ^c	0/0
2 SW	0/0 ^c	0/0
2 BR	0/0 ^c	1/1
2 BS	0/0 ^c	0.5/0.5
3 T	0/0 ^c	0/0
3 SB	0/0 ^c	0/0
3 SW	0/0 ^c	0/0
3 BR	0/0 ^c	1/1
3 BS	0/0 ^c	0/0
4 T	0/0 ^c	0/0
4 SB	0/0 ^c	0/0
4 SW	0/0 ^c	0/0
4 BR	0/0 ^c	0/0
4 BS	0/0 ^c	0/0
5 T	0/0 ^c	0/0
5 SB	0/0 ^c	0/0
5 SW	0/0 ^c	0/0
5 BR	0/0 ^c	0/0
5 BS	0/0 ^c	0/0
6 T	0/0 ^c	0/0
6 SB	0/0 ^c	0/0
6 SW	0/0 ^c	0/0
6 BR	0/0 ^c	0/0
6 BS	0/0 ^c	0/0

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^aNumber indicates cycle

- 1 = Pennwalt's with 20 g added organic carbon
- 2 = Pennwalt's with 40 g added organic carbon
- 3 = Pennwalt's with 80 g added organic carbon
- 4 = Formula I with 20 g added organic carbon
- 5 = Formula I with 40 g added organic carbon
- 6 = Formula I with 80 g added organic carbon

^bLetters indicates test item

- T = towel
- SB = black sock
- SW = white sock
- BR = men's briefs
- BS = boxer-style men's shorts

^cAll samples tested in duplicate

C. AATCC-100

After the plate counts were obtained, each sample's bacterio-static ability was determined, as 0/0 reduction. This indicates the percentage of inoculated bacteria that could not be recovered (assumed to have been rendered inviable) after the exposure period. In addition, the percent inhibition was calculated. This quantity provides a measure of how well the sample prevented or decreased the rate of bacterial reproduction.

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The table below summarizes the results obtained for the AATCC-100 tests.

Sample	S.aureus		E.coli	
	% Reduction	% Inhibition	% Reduction	% Inhibition
1T	51	100	100	100
1SB	0	16	0	99
1SW	98	100	92	100
1BR	0	51	94	100
1BS	0	0	76	100
2T	0	68	0	0
2SB	0	17	81	100
2SW	0	68	0	96
2BR	0	99	99	100
2BS	57	100	97	100
3T	0	65	48	100
3SB	0	31	82	100
3SW	0	93	0	0
3BR	17	100	52	100
3BS	0	0	0	77
4T	97	100	25	100
4SB	0	98	0	12
4SW	51	100	97	100
4BR	87	100	18	100
4BS	0	0	0	0
5T	89	100	0	95
5SB	0	0	0	0
5SW	87	100	63	100
5BR	0	52	100	100
5BS	0	0	39	100
6T	75	100	14	100
6SB	0	44	0	0
6SW	79	100	0	85
6BR	100	100	0	69
6BS	0	0	91	100

Although both formulas demonstrated some antibacterial activity, neither one showed significantly better results than the other in this test.

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D. AOAC Germicidal Equivalency

The table below summarizes the results obtained for this phase of testing. The samples were both tested in solutions 10 times and 5 times more concentrated than their final concentration under laundry conditions.

		<u>Subculture Tube</u>									
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>
Chlorine:	200 ppm	-	-	+	+	+	+	+	+	+	+
	100 ppm	+	+	+	+	+	+	+	+	+	+
	50 ppm	+	+	+	+	+	+	+	+	+	+
Sample:	10x	+	+	+	+	+	+	+	+	+	+
Pennwalt's	5x	+	+	+	+	+	+	+	+	+	+
Sample:	10x	+	+	+	+	+	+	+	+	+	+
Formula I	5x	+	+	+	+	+	+	+	+	+	+
- no growth											
+ growth											

<u>Phenol Dilution</u>	<u>5 min.</u>	<u>Phenol Resistance</u>		<u>15 min.</u>
			<u>10 min.</u>	
1:60	+		+	-
1:70	+		+	+
1:80	+		+	+

E. AOAC Sanitizer Test

The sanitizer tests were run on test solutions which were 10 times more concentrated than their final concentration under laundry conditions. The table below summarizes the results.

<u>Sample</u>	<u>Colony Forming Units/ml (average)</u>	<u>Percent Reduction</u>
Control	1.08×10^{11}	0
Pennwalt's	5.00×10^8	99.537
Formula I	3.80×10^7	99.965

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F. Breaking Strength

The table below summarizes the results of all breaking strengths.

<u>Sample</u>	<u>Breaking Strengths, Average (lbs.)</u>			
	<u>Towels</u>	<u>% loss</u>	<u>BS</u>	<u>% loss</u>
Control	113/108 ^a	-	60/36	-
Pennwalt +20g ^b	102/015	10/3	64/39	0/0
Pennwalt +40g	95/07	16/1	62/35	0/3
Pennwalt +80g	93/108	18/0	57/29	5/19
Formula I +20g	108/104	4/4	60/36	0/0
Formula I +40g	101/104	11/4	59/39	2/0
Formula I +80g	102/105	10/3	62/40	0/0

^aAll results indicate both the warp and filling directions as warp/filling.

^b20g, 40g or 80g indicates the amount of organic material added to the wash cycle.

G. Primary Skin Irritation

<u>Sample Id:</u>	<u>Erythema & Eschar</u>	<u>Period</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>Avg</u>
	abraded	24 hrs	0	0	0	0	0	0	0
	abraded	72 hrs	0	0	0	0	0	0	0
All samples tested	unabraded	24 hrs	0	0	0	0	0	0	0
	unabraded	72 hrs	0	0	0	0	0	0	0
<u>Edema</u>									
	abraded	24 hrs	0	0	0	0	0	0	0
	abraded	72 hrs	0	0	0	0	0	0	0
	unabraded	24 hrs	0	0	0	0	0	0	0
	unabraded	72 hrs	0	0	0	0	0	0	0

Total

Primary Irritation Score (Total + 4) 0

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H. Aesthetic Evaluation

The following statements summarize the findings of the test panel. Each statement is followed by a number indicating the number of panelists who noted that particular observation; e.g., (3/5) indicates that 3 out of the 5 panelists made that observation.

1. Formula I, at low and medium levels of organic material, appears the whitest and cleanest (5/5).
2. Both formulas, at the highest level of added organic material, appear somewhat grey (5/5).
3. Formula I, at low and medium levels of organic material, feels more stiff or rough than the other results (1/5) - compare with statement #4.
4. Formula I, at low and medium levels of organic material, feels softer than the other results (1/5) - compare with statement #3.
5. Neither of the formulas yields results with any discernible odor (4/5).
6. Pennwalt's formula, at low level of organic material, appears to have a slightly yellowish cast (1/5).
7. Pennwalt's formula shows grayer results at medium rather than high level of organic material (2/5).

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Discussion

In situ activity. This refers to bacteriostatic activity of the formulae in liquid form. Three phases of the testing were used to determine this parameter: (1) AOAC Chlorine Germicidal Equivalent Test, (2) AOAC Germicidal and Detergent Sanitizers Test and (3) Examination of Wash Waters. The results of the sanitizer test indicated that Formula I and Pennwalt's Formula reduced bacterial numbers by 99.965% and 99.537% respectively. This implies that Formula I may be slightly more effective as an inhibitory agent. This conclusion is supported by the results of the wash water examination, which showed slightly lower bacterial numbers recovered from Formula I treatment than from Pennwalt's Formula treatment. Neither of the formulations demonstrated any bacteriostatic activity in the Germicidal Activity Test, in which the samples are compared to chlorine for antimicrobial activity.

Residual activity. This refers to any bacteriostatic activity demonstrated by the laundered fabrics, after treatment with the respective test formulas. Two phases of the testing were used to determine this parameter: (1) AATCC-100, and (2) Petrocci-Clark Antimicrobial Fabric Test.

Both formulas demonstrated residual antimicrobial activity when tested by AATCC-100, but results indicate that neither one of the test formulas is significantly more effective than the other. The Petrocci-Clark test, which is not as sensitive as AATCC-100, demonstrated no significant antimicrobial activity from either formula. However, some samples from Pennwalt's formula showed measurable activity, and none from Navy Formula I showed measurable activity.

Additional residual effects. Neither formula demonstrated or caused any dermal irritation.

Both formulas apparently caused a loss in breaking strength, particularly in a blended fabric (terry towels). Both of the formulas showed more of this loss with higher levels of organic material. However, Pennwalt's Formula showed somewhat more loss of breaking strength than did Formula I.

Evaluation of laundered goods. Although there are a few instances of conflicting observations among the panel members, a few conclusions may be drawn from the summary. First, Formula I at low to medium levels of contamination results in cleaner and whiter clothing articles. Second, at higher levels of contamination, both formulas appear to be approximately equal in producing "blue" or "grey" colored laundry. There is no clear trend as to which formula might produce "softer" fabrics, and, finally, neither formula seems to result in any discernible odors.

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Conclusions:

Based on the Results and Discussion, we have drawn the following conclusions.

1. Neither formula is clearly more effective than the other as an initial disinfectant; however, there was some data appearing to favor Navy Formula I in this capacity, under the conditions tested.
2. Although fabrics washed with both the formulas show residual antimicrobial activity, there is no clear indication that one is superior to the other. Again, however, some of the data obtained may indicate that Pennwalt's Formula shows more activity than Navy Formula I.
3. None of the fabrics, tested with either of the formulas, showed any irritating effects.
4. Fabrics treated with Pennwalt's Formula showed somewhat more loss in breaking strength than those treated with Navy Formula I, as determined by the samples as submitted. However, further work on this, using more sample duplicating, may be required.
5. Fabrics washed with Navy Formula I come out cleaner and whiter than those washed with Pennwalt's Formula.

APPENDIX E

MEMO REPORT
85-F-14Evaluation of Pennwalt Detergent/Conditioner Formulation for
Navy Shipboard LaundryI. Introduction:

The Navy currently uses a five component detergent formulation (Formula I) for cleaning cotton and cotton/synthetic blends, either white or with fast colors. The washing is done at 71°C (160°F). There is a new detergent formulation consisting of two components (a detergent and a conditioner) which is manufactured by Pennwalt Corp., Philadelphia, PA. This new formulation is being tested as a replacement for the present Navy detergent formulation (Formula I). The Pennwalt formulation contains a biostat (proprietary), and the washing can be done at a lower temperature than the 71°C (160°F) presently used with Formula I. The use of lower temperature will not only save energy, but other clothing (acrylic, wool, nylon or their blends) may now be washed. Therefore, one detergent formulation may be used for most of the laundry needs of the Navy, instead of the multiple detergent formulations currently required.

The objective of this project was to determine the bactericidal efficacy of the new Pennwalt formulation to the present Navy detergent (Formula I) at comparable and lower temperatures.

II. Materials and Methods

1) Washwheel - The Test Washer was a Model 24-20, Powercom (Troy, NY). The capacity of the washwheel is 9 kg (20 lbs.), with 66 liters (18 gallons) total volume. The washwheel is connected to pressurized air, cold and hot water and steam. The temperature of the wash can be adjusted from ambient conditions up to 82°C (180°F).

2) Detergent - The current detergent formulation used by the Navy consists of: a) a low sudsing low phosphate synthetic detergent called Formula I (MIL-P-D-245E); b) Alkali (CID AA-876); c) Non-ionic detergent (MIL-D-16791-F); d) Organic bleach (CID AA-1664) and e) Sour/Conditioner (CID AA-1374).

The Pennwalt detergent formulation under test contains: a) Pennwalt Detergent (N-Det-2) and b) Pennwalt Conditioner.

3) Soiling Mixture - The soiling mixture prepared in the laboratory for the soiling of the laundry clothing had the following composition, 100 g of soil, 50 g of motor oil and 50 g of vegetable oil. The soil was prepared by mixing equal amounts of: a) sand, b) cow manure, and c) top soil (these three ingredients were purchased from a local nursery). The soil was steam sterilized at 120°C for 60 minutes before the soil was mixed with the oils. The soiling mixture was steam sterilized for 30 minutes at 120°C before addition to the wash load.

The soiling mixture was applied at the rate of 200 g per 9 kg of clothing.

4) Microorganisms - Three microorganisms, *Escherichia coli* (ATCC 11229 and C-3000), *Staphylococcus aureus* (ATCC 6538) and *Bacillus globigii* (*Bacillus subtilis* var. *niger*) spores (from E. Merck Co., NJ) were used in the study. *E. coli* and *S. aureus* were maintained on Nutrient Agar (Difco Laboratories, Detroit, MI) slants, and grown in Nutrient Broth (Difco Laboratories), before they were harvested. An aliquot of bacterial suspension was diluted with 0.9% sterile sodium chloride solution (NSS) and spread plated on Nutrient Agar plates to determine the total number of bacteria added to the wash. In the case of *B. globigii*, 100 g of spore was suspended in 50 ml of NSS, mixed thoroughly, and an aliquot was diluted with NSS, to give 30 to 300 colony forming units (CFU) per petri dish. The petri dish contained the following nutrients per liter: Nutrient Broth (Difco Laboratories), 8.0 g; Bacto Agar (Difco Laboratories), 15.0 g; KCl, 1.0 g; $MgSO_4 \cdot 7H_2O$, 0.25 g; glucose, 5.0 g; Yeast Extract (Difco Laboratories), 0.1 g; $FeSO_4 \cdot 7H_2O$, 0.278 mg; and $MnCl_2 \cdot 4H_2O$, 2.0 mg. All three microorganisms were incubated at 37°C for 18-24 hours for enumeration on plates.

5) Agar Difussion Method

The biocidal effect of the different components of the detergent formulations were studied by the agar diffusion method using 1.5% Nutrient Agar with a 0.7% Nutrient Agar overlay in petri dishes. The Nutrient Agar overlay was seeded with microorganisms at 50°C, and 1.0 cm diameter cotton duck discs soaked with the different components of the detergent formulations were placed on the surface of the overlay. The plates containing microorganisms were incubated at 37°C for 18-24 hours. The Table VI and Figures 1 through 7 give the results of this study.

6) Swatch System

The microorganisms were applied on swatches 5.08 cm x 5.08 cm (2 inch x 2 inch) cotton duck (100% bleached cotton) and stapled onto clothing used for the laundry. Another set of swatches, 10.16 cm x 10.16 cm (4 inch x 4 inch) (100% bleached cotton duck) were stapled onto laundry clothing and later extracted with NSS to determine the residual microorganisms left in the clothing after the wash and rinse cycles.

7) Wash Cycles

The washing machine was loaded with 9.0 kg clothing containing socks, underwear, bath towels and laboratory coats (either cotton or cotton/polyester blends). The water temperature was adjusted as per the experiment. The last cycle (sour/conditioner) was set 17°C lower than the wash cycle as per MIL-P-D-245E, Navy Wash Formula I. The following wash cycle temperatures were tested 49°C (120°F), 60°C (140°F) and 71°C (160°F). The details of the wash/rinse/sour cycles, including the temperature and concentrations of different components of the detergent formulations, are given in Table I.

The total volume of the washwheel was 66 liters (18 gallons). The water carryover from one cycle to the next was determined by weighing the wet clothing after each cycle. The details of water drained and/or carried over to the next cycle are given in Table II. The bacterial counts recovered from each cycle were calculated based on the volume of water drained from each cycle.

Controlled laundry cycles were also run with soiled cloth and with E. coli or S. aureus, but without any detergent or sour/conditioner. These controls were run, in order to evaluate the effect of the water temperature on the survival of the test bacteria in the clothing. The results are presented as log reductions of bacterial counts at wash temperatures (without detergents) of 49°/32°C, 60°/43°C, or 71°/54°C (Table III). The calculation of log reduction of bacterial counts was based on the following parameters: a) the total bacterial load added to the clothing, b) the number of bacteria recovered from all the wash/rinse/sour cycles, and c) the number of bacteria left in the cloth swatches after the wash. The data given in Table II was taken into consideration for the calculation of the total number of bacteria recovered from all the cycles (see parameter (b) above. For comparison of efficacy of kill of microorganism, a six log reduction over baseline was considered adequate disinfection. The bacterial loss as log reduction with the Formula I and the Pennwalt formulations at different laundry temperatures are given in Table IV. The log reduction in bacterial counts was calculated in the same manner as in Table III.

The pH of the water collected from each cycle of the laundry is given in Table V. The pH was monitored during detergent runs as well as during control runs without detergent.

III. Results

The results clearly indicate that there was significant reduction of bacterial counts (E. coli and S. aureus) at 49°C even during washing without detergents. This log reduction (≈5.0 log reduction at 49°C) in the control cycle may be due to bacterial kill by temperature, low osmolarity of wash water, the physical action of the laundry cycle, or other unaccounted losses during the wash. There was a corresponding >11.0 log reduction of the vegetative bacteria at 60°C and 71°C. The data in Table IV clearly indicate that with vegetative microorganisms, the detergent formulations (the present Navy Formula I and the Pennwalt) killed almost all of the bacteria (greater than an 11.0 log reduction). However, with spores of B. globigii, the reduction was not significant (≈1.0 log reduction).

There was no significant difference between the present Navy detergent (Formula I) and the Pennwalt with respect to kill of B. globigii spores or the vegetative bacteria (E. coli and S. aureus).

There was some inhibition of growth with S. aureus at this concentration. When Pennwalt sour was tested at 129 ppm (10 times the user concentration) there was some inhibition of growth of E. coli (ATCC 11229 and C-3000) and S. aureus (ATCC 6538), but not of B. globigii spores.

The pH determinations of water in the different wash cycles indicated that there was no difference in the pattern with the two detergent formulation.

IV. Conclusions

The results indicate that there was no significant difference with respect to bacterial kill, when the Pennwalt Detergent/Sour was used as compared with the present Navy detergent formulation (Formula I). Both formulations provided similar reductions in vegetative bacterial numbers (>11 log), while spore numbers were virtually unaffected.

Joseph Akkara
JOSEPH AKKARA, Ph.D.
Materials Protection Branch
Materials Protection & Biotechnology Div
Science & Advanced Technology Laboratory

DLK *DLK*
MRR *MRR*
AMK *AMK*

TABLE I
NAVY LAUNDRY WASH CYCLE

Operation	Time (minutes)	Temp ($^{\circ}\text{C}$)	<u>Supplies/9 Kg of Load</u>	
			Formula I ^a	Pennwalt
Break/Suds	10.0	b	45.4 g Formula I 90.8 g alkali 11.4 g nonionic detergent	91.0g N-Det-2
Drain	1.0	-	-	-
Bleach	6.0	b	11.4 g of organic bleach	-
Drain	1.0	-	-	-
Spin	1.0	-	-	-
Rinse 1	3.0	b	-	-
Drain	1.0	-	-	-
Rinse 2	3.0	b	-	-
Drain	1.0	-	-	-
Sour/Conditioner	4.0	c	11.4 g of Sour	8.5 g of Pennwalt Conditioner
Drain	1.0	-	-	-
Spin	4.0	-	-	-

NOTE:

^aFormula I = MIL-P-D-245 E., Alkali = CID- A-A-876., Nonionic detergent = MIL-D-16791-1
Organic Bleach = CID- A-A-1664., Sour = CID- A-A-1374

^bthe temperature was at either 49 $^{\circ}\text{C}$, 60 $^{\circ}\text{C}$, or 71 $^{\circ}\text{C}$.

^cthe corresponding temperature for the sour/conditioner cycle was at 32 $^{\circ}\text{C}$,
43 $^{\circ}\text{C}$ and 54 $^{\circ}\text{C}$ respectively

TABLE II

Flow Chart for the Water Input and Drain During Washing Cycle

Washing Cycle (time min)	INPUT		OUTPUT
	Load/Carryover from previous cycle	Fresh Water	
Break/Suds (10 min)	9 Kg Clothing	+ 59 Liter Water	Drain → 42.5 L waste
Bleach (6.0 min)	16.5 L Carryover	+ 42.5 L Water	Drain → 54.8 L waste + Spin
Rinse Cycle #1 (3.0 min)	4.2 L Carryover	+ 54.8 L Water	Drain → 42.5 L waste
Rinse Cycle #2 (3.0 min)	16.5 L Carryover	+ 42.5 L Water	Drain → 42.5 L waste
Sour/Conditioner (4.0 min)	16.5 L Carryover	+ 42.5 L Water	Drain → 59 L waste + Spin
TOTAL = 241.3 L Freshwater			241.3 L Wastewater

TABLE III
Navy Laundry without Detergent at Various Temperatures
 (log reduction⁺ in bacterial counts)

Microorganism	Temperature of Wash		
	49°C	60°C	71°C
<u>E. coli</u> (ATCC 11229)	4.9	> 11.0	> 11.0
<u>S. aureus</u> (ATCC 6538)	5.0	> 11.0	> 11.0

+ log reduction in this experiment is defined as the reduction in the total number of bacteria added initially. This reduction is calculated from the number of bacteria recovered from all the cycles of washing based on the experimental results given in Table II and explained in the text.

TABLE IV
Log Reduction⁺ of Bacterial Counts in Navy Laundry at Difference Temperatures

Microorganisms	TEMPERATURE OF WASH					
	49°C		60°C		71°C	
	Formula I	Pennwalt	Formula I	Pennwalt	Formula I	Pennwalt
<u>E. coli</u> (ATCC 11229)	> 11.0	> 11.0	> 11.0	> 11.0	> 11.0	> 11.0
<u>S. aureus</u> (ATCC 6538)	> 11.0	> 11.0	> 11.0	> 11.0	> 11.0	*
<u>B. globigii</u>	0.64	0.85	1.03	1.26	1.35	1.36

* No data

+ log reduction in this experiment is defined as the reduction in the total number of bacteria added initially. This reduction is calculated from the number of bacteria recovered from all the cycles of washing based on the experimental results given in Table II and explained in the text.

TABLE V

pH Profile of the Wash/Rinse Water in Different Cycles of Navy Laundry

TEMPERATURE	NO DETERGENT			FORMULA I			PENNWALT		
	49°C	60°C	71°C	49°C	60°C	71°C	49°C	60°C	71°C
Break/Suds	7.8	8.0	8.2	11.8	11.5	11.7	10.5	10.5	10.5
Bleach	7.9	8.2	8.3	11.0	11.0	11.0	10.0	10.0	9.8
Rinse I	8.0	8.3	8.3	9.5	9.5	9.4	8.6	8.8	8.8
Rinse II	8.0	8.3	8.3	8.9	9.0	9.0	8.5	8.5	8.7
Sour/Conditioner	8.0	8.2	8.3	6.9	7.1	7.5	6.0	6.7	6.7
Break/Suds	7.8	8.0	8.1	11.7	11.5	*	10.3	10.4	*
Bleach	8.0	8.1	8.1	11.1	10.9	*	9.9	9.8	*
Rinse I	8.0	8.2	8.1	9.6	9.7	*	8.9	8.6	*
Rinse II	8.0	8.2	8.2	9.0	9.0	*	8.6	8.3	*
Sour/Conditioner	8.0	8.2	8.2	6.7	7.3	*	6.3	5.8	*
Break/Suds	*	*	*	11.4	12.3	12.2	11.2	11.0	10.6
Bleach	*	*	*	11.7	11.6	11.4	10.5	10.3	10.1
Rinse I	*	*	*	9.7	9.7	9.7	9.1	9.1	9.0
Rinse II	*	*	*	9.1	9.2	9.2	8.7	8.6	8.7
Sour/Conditioner	*	*	*	6.5	6.9	7.3	6.7	5.5	6.6

* No data

TABLE VI

Study of the Biocide Efficacy of Components of Detergent Formulations

<u>Test Material</u>	<u>E. coli</u>		<u>S. aureus</u>	<u>B. globigii</u>
	3000	ATCC11229	ATCC6538	
Present Navy Det. (Formula I)	*	a	a	a
Navy Bleach	*	a	a	a
Present Navy Sour	*	a	a	a
N-Det-2 (Penwalt)	*	a	a	a
Pen-Sour	*	a	b	a
Pen-Sour 129 mg/100 ml (w/v)	b	b	b	*
Pen-Sour 129 mg, 100 ml (w/v) pH 7.0	b	*	b	*
Pen-Sour (129 mg/100 ml) (w/v) pH 3.5	b	*	b	*
Present Navy Sour (129 mg/100 ml) (w/v)	a	a	a	*

NOTE: Test materials 1 to 5 were at user concentration (see Table I)

a = no inhibition of growth

b = inhibition of growth

* = no data

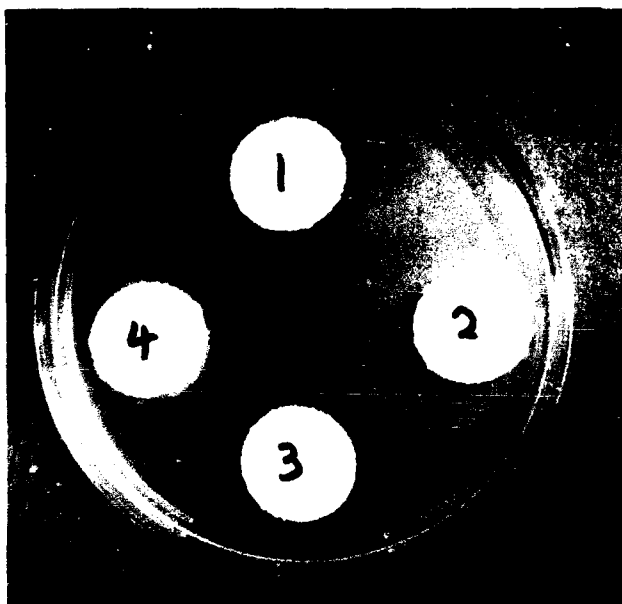


Figure 1. E. Coli C-3000

- | | |
|--------------------------|---------------|
| 1. Penn Sour | 129 mg/100 ml |
| 2. Sterile Sod. Chloride | 900 mg/100 ml |
| 3. Penn Sour | 129 mg/100 ml |
| 4. Sterile Sod. Chloride | 900 mg/100 ml |

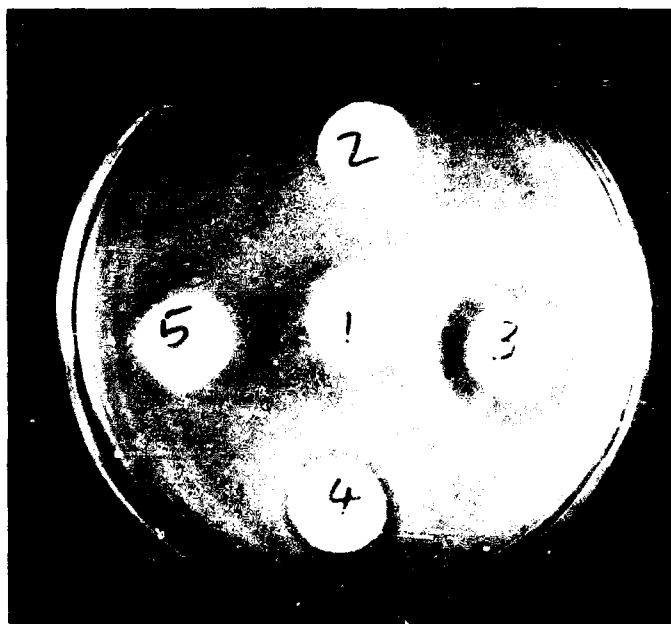


Figure 2. E. Coli C-3000

- | | |
|-------------------|----------------------|
| 1. Water | |
| 2. Citrate buffer | 0.1M, pH 3.6 |
| 3. Penn Sour | 129 mg/100 ml pH 7.0 |
| 4. Penn Sour | 129 mg/100 ml pH 3.6 |
| 5. Navy Sour | 129 mg/100 ml |
| (CID-A-A-1374) | |

Figure 3. E. Coli ATCC 11229

- | | | |
|---|-----------------|-----------------|
| 1. Formula I (MIL-P-D-245E) | 68.9 mg | } Per
100 ml |
| Alkali (CID-A-A-876) | 137.6 mg | |
| Nonionic detergent
(MIL-P-D-16791-F) | 17.3 mg | |
| 2. Bleach (CID-A-A-1664) | 17.3 mg/100 ml | |
| 3. Navy Sour (CID-A-A-1374) | 17.3 mg/100 ml | |
| 4. Penn N-Det 2 | 137.6 mg/100 ml | |
| 5. Penn Sour | 12.9 mg/100 ml | |

Figure 4. E. Coli ATCC 11229

- | | | |
|---|-----------------|-----------------|
| 1. Formula I (MIL-P-D-245) | 68.9 mg | } Per
100 ml |
| Alkali (CID-A-A-876) | 137.6 mg | |
| Nonionic detergent
(MIL-P-D-16791-F) | 17.3 mg | |
| 2. Bleach (CID-A-A-1664) | 17.3 mg/100 ml | |
| 3. Penn N-Det 2 | 137.6 mg/100 ml | |
| 4. Penn Sour | 12.9 mg/100 ml | |
| 5. Penn Sour | 129 mg/100 ml | |

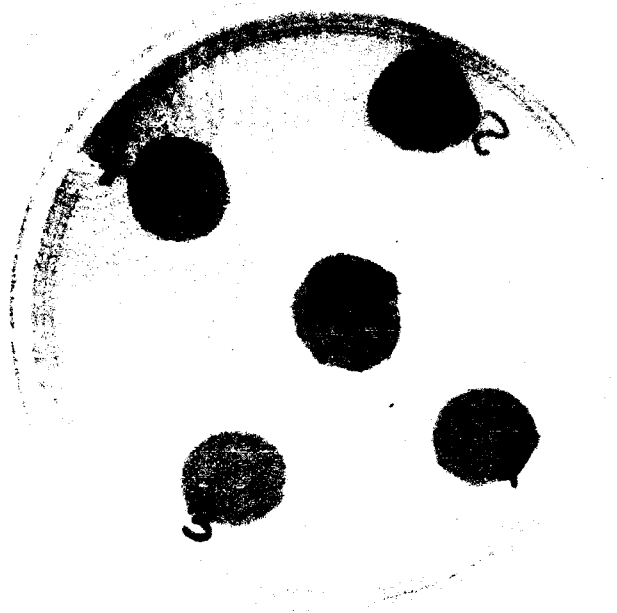


Figure 5. S. Aureus ATCC 6538

- | | | |
|---|-----------------|---------------|
| 1. Formula I (MIL-P-D-245E) | 68.9 mg | Per
100 ml |
| Alkali (CID-A-A-876) | 137.6 mg | |
| Nonionic detergent
(MIL-P-D-16791-F) | 17.3 mg | |
| 2. Bleach (CID-A-A-1664) | 17.3 mg/100 ml | |
| 3. Navy Sour (CID-A-A-1374) | 17.3 mg/100 ml | |
| 4. Penn N-Det-2 | 137.6 mg/100 ml | |
| 5. Penn Sour | 12.9 mg/100 ml | |

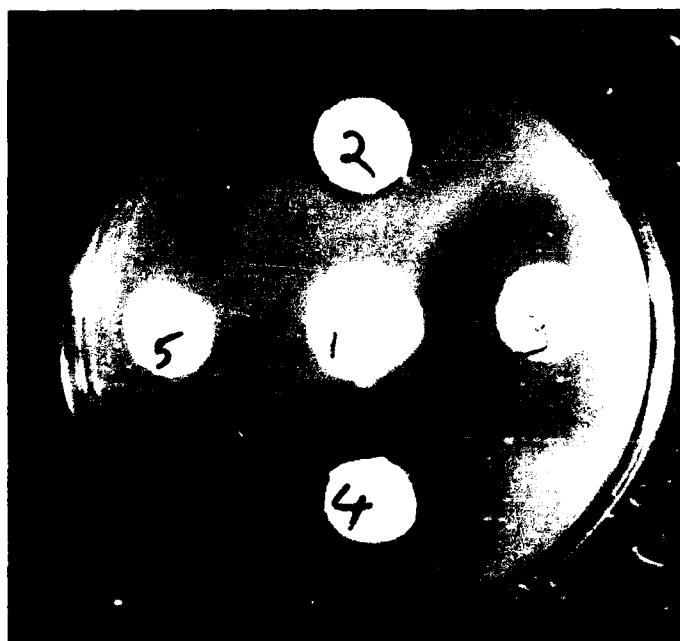


Figure 6. S. Aureus ATCC 6538

1. Water
2. Citrate Buffer pH 3.6 0.1M, pH 7.6
3. Penn Sour pH 3.6 129 mg/100 ml
4. Penn Sour pH 7.0, 129 mg/100 ml
5. Navy Sour (CID-A-A-1374) 129 mg/100 ml

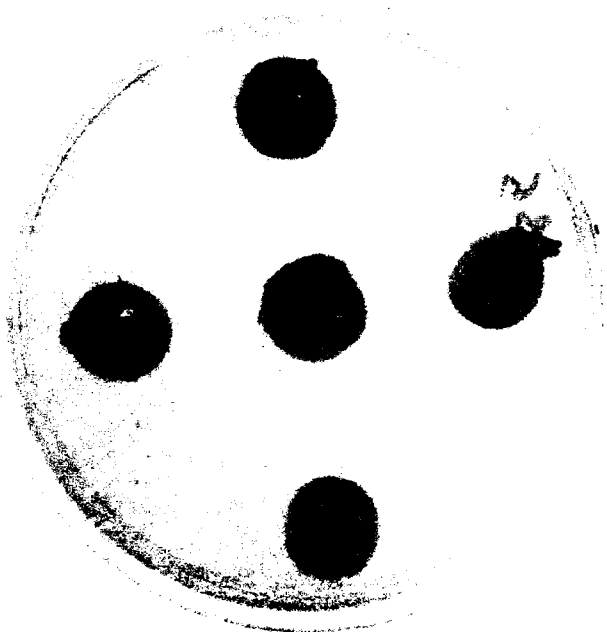


Figure 7. B. Globigii

- | | | |
|---|-----------------|---------------|
| 1. Formula I (MIL-P-D-245-E) | 68.9 mg | Per
100 ml |
| Alkali (CID-A-A-876) | 137.6 mg | |
| Nonionic detergent
(MIL-P-D-16791-F) | 17.3 mg | |
| 2. Bleach (CID-A-A-1664) | 17.3 mg/100 ml | |
| 3. Navy Sour (CID-A-A-166) | 17.3 mg/100 ml | |
| 4. Penn N-Det-2 | 137.6 mg/100 ml | |
| 5. Penn Sour | 12.9 mg/100 ml | |

APPENDIX F



PENNWALT BUILDING, THREE PARKWAY, PHILADELPHIA, PENNSYLVANIA 19102

CHEMICALS • EQUIPMENT • HEALTH PRODUCTS

July 30, 1985

Ms. Maria F. Demorais
Textile Chemist - Materials Research Division
Navy Clothing & Textile Research Facility
21 Strathmore Road
Natick, MA 01760

Dear Fernanda:

I am enclosing test data results prepared by Pennwalt's King of Prussia Laboratories and Quality Control Laboratory. Test data is reported in Tables I-III.

TABLE I

Evaluates whiteness retention, tensile strength loss and soil removal on 100% cotton and 65/35 poly-cotton.

Comments:

1. Whiteness retention averaged higher on all classifications with N-DET-2 than with Navy products.
2. Tensile strength loss averaged slightly higher with N-DET-2 than with Navy products; however, tensile strength loss with both was slightly higher than normal for ten wash tests. This could possibly be attributed to loads run in the 100 lb. Dyna-Wash where temperatures sometimes climbed to as high as 190°F.
3. Soil removal with N-DET-2 was generally higher than with Navy products.

TABLE II

Evaluation of anti-bacterial protection.

Comments:

1. No positive anti-bacterial protection was indicated on either whites or blues with Navy products.
2. N-DET-2 and Sour/Conditioner gave positive protection on whites.
3. Absence of anti-bacterial protection on blues with N-DET-2 and Sour/Conditioner could possibly be due to the sometimes malfunctioning sour supply injection hopper on the 100 lb. Dyna-Wash.

TABLE III

Evaluation of test swatches treated with Sour/Conditioner applied at the one ounce per cwt of fabric use level for the U.S.S. Ranger tests.

Comment:


1. Positive protection shown for both Gram Positive and Gram Negative test organisms.

SUMMARY

1. The soil removal, whiteness retention and tensile strength loss results with N-DET-2 and Sour/Conditioner would appear to be equal to or slightly better than with Navy products.
2. No positive anti-bacterial protection was indicated with Navy products.
3. Positive anti-bacterial protection was shown on whites with N-DET-2 and Sour/Conditioner and it is reasonable to assume that the same anti-bacterial protection would be shown on all Navy classifications if the Sour/Conditioner was injected or added on the basis of one ounce per 100 lb. of fabrics processed.

We will look forward to receiving a copy of the test results you receive covering your Natick wash tests and IFI swatch tests so that we can fully evaluate the test work done on N-DET-2 and Sour/Conditioner.

Sincerely,


W. R. Downing
Marketing Specialist
Textile Chemicals Department

/s1

cc: Mr. Maurice W. Roy
Senior Scientist
Navy Clothing and Textile Research Facility
21 Strathmore Road
Natick, MA 01760

bcc: N28, M67, E49, R58, C70, M28, G54

T A B L E I

<u>FORMULA USED</u>	<u>NO. OF WASHES</u>	<u>COLOR</u>	<u>100% COTTON</u>		<u>POLY-COTTON</u>	
			<u>% WHITENESS RETENTION</u>	<u>% TENSILE LOSS</u>	<u>% WHITENESS RETENTION</u>	<u>% SOIL REMOVAL</u>
Navy Products	1	White	--	--	99	5
Navy Products	10	White	92	11	99	30
N-DET-2	1	White	--	--	102	3
N-DET-2	10	White	99	19	100	34
Navy Products	1	Blues	--	--	81	-10
Navy Products	10	Blues	56	10	67	8
N-DET-2	1	Blues	--	--	85	0
N-DET-2	10	Blues	69	9	82	26



QUALITY CONTROL LABORATORY

1000 INDUSTRIAL - 3RD FLOOR • KING OF PRUSSIA, PA. 19406 • TEL. 215-261-1100

TABLE 2

July 16, 1985

Clair Warren Graver
Project Leader
Textile Industries
Product Development Laboratories
900 First Avenue
King of Prussia, PA. 19406

LABORATORY REPORT
AATCC Test Method 90-1977 with Appendix A
(Refrigeration 5°C 16-18 hours)

TABLE 2)

Articles Tested	Gram Positive Test Organism*	Gram Negative Test Organism**	Remarks
6039-70-2 Navy Formula 0.5	Whites	0.0	Partial antibacterial protection
6039-70-3 Navy Formula 0.0	Blues	0.0	Zero antibacterial protection
6039-70-6 N-DET-2, 4.0 Sour-Conditioned	Whites	1.0	Positive antibacterial protection
6039-71-8 N-DET-2, 0.0 Sour-Conditioned	Blues	0.0	Zero antibacterial protection

*ATCC-6538-Staphylococcus aureus

**ATCC-4352-Klebsiella pneumoniae

Quality Control Laboratory

Clair Warren Graver



QUALITY CONTROL LABORATORY

1205 INDUSTRIAL HIGHWAY • P.O. BOX 514 • SOUTHAMPTON, PA 18966 • (215) 673-4900 • (215) 355-3900

TABLE 3

A. F. Zimmermann

A. D. Schopbach

DETERMINATION OF ANTIBACTERIAL ACTIVITY OF TREATED FABRICS

Month Submitted:

June 17, 1985

Source of Text Fabrics:

6-4-85

Pennwalt Corporation
Textile Specialties Dept.
Three Parkway
Philadelphia, Pa. 19102

Attn: Mr. H.F. Convery
Health Care
Industry Manager

Pennwalt Representative:

Tim Morris

LABORATORY REPORT

AATCC Test Method 90-1977 with Appendix A
(Refrigeration 5°C 16-18 hours)

ZONE OF INHIBITION (mm)

Articles Tested	Gram Positive Test Organism*	Gram Negative Test Organism**	Remarks
<u>Pieces of Sheet</u>			
6039 - 63A	8.0	4.0	Positive antibacterial protection
6039 - 63B	8.0	4.5	Positive antibacterial protection
6039 - 63C	8.5	4.5	Positive antibacterial protection
6039 - 63D	8.5	5.0	Positive antibacterial protection

*ATCC-6538 — *Staphylococcus aureus*

**ATCC 4352 — *Klebsiella pneumoniae*

COMMENTS:

Q C Inc
QUALITY CONTROL LABORATORY